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Thomas, Joseph D.
Thomas, S. B.
Thompson, Robert M.
Thorp, Harry W.
Toch, Henry M.
Todt, Edward G.
Tomikawa, Naoji.

Vanderbilt, Aaron.
Van Duzer, Louis S.
Vassileff, Dimitry.
Veit, Richard C.
Vreeland, Charles E.

Wales, Charles M.
Welles, Roger, Jr.
Whitaker, F. B.
White, George A.
Whiton, Chauncey G.
Williams, Ralph D.
Williams, William E.
Wood, David.
Wood, Henry A. W.
Wright, William L.

Young, William J. J.

JUNIORS.

Bretteville, Alex. de.

Carlsen F.
Colley, G. A.
Chapman, Lawrence B.
Colby, Haldwell S.
Cook, Fayette A.
Cutler, Edward O.

Erdman, George K.

Fermann, Wilhelm E.
French, Francis J.

Hanson, Ralph T.
Hermanrud, Torbjorn.
Herrick, Dayton E.
Holbrook, Gordon G.

Hogan, Robert L.
Hubbell, Charles W.
Hunsaker, Jerome C.

Mills, Roy P.
Musham, Harry A.

Newton, G. A.
Norton, William J.

Rimmer, A. Cyril.

Schmidt, John D.

ARTICLES OF INCORPORATION.

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

STATE OF NEW YORK,
CITY AND COUNTY OF NEW YORK, } ss:

We, the subscribers, WM. H. WEBB, CHAS. H. CRAMP, GEORGE E. WEED, H. TAYLOR GAUSE, WILLIAM T. SAMPSON, HORACE SEE, FRANK L. FERNALD, FRANCIS T. BOWLES, WASHINGTON L. CAPPS, EDWIN D. MORGAN, GEORGE W. QUINTARD, HARRINGTON PUTNAM and JACOB W. MILLER, being persons of full age and citizens of the United States, of whom a majority—namely, William H. Webb, George E. Weed, Horace See, Edwin D. Morgan, George W. Quintard, Harrington Putnam, Frank L. Fernald, and Jacob W. Miller are citizens of and residents of and within this State, desiring to associate ourselves for scientific purposes under, and pursuant to, an Act of the State of New York providing for the incorporation of benevolent, charitable, scientific, and missionary societies, passed April 12, 1848, and the several acts amending or supplementing the same, do hereby, in accordance with the requirements thereof, certify as follows:—

First. The name or title by which the Society shall be known in law is THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

Second. The particular business and objects of such Society are the promotion of practical and scientific knowledge in the arts of shipbuilding and marine engineering and the allied professions, and in furtherance of this object, to hold meetings for social intercourse among its members, and the reading and discussion of professional papers, and to circulate by means of publication the knowledge thus obtained.

Third. The number of directors, trustees, or managers to manage the Society shall be seven, and shall consist of a President, a Secretary, and five Members of Council.

Fourth. The names of the trustees, directors, or managers of the Society for the first year of its existence are:—President, Clement A. Griscom; Secretary, Washington L. Capps; Members of Council, Francis T. Bowles, H. Taylor Gause, Chas. H. Loring, Lewis Nixon, Harrington Putnam.

Fifth. The business of the Society is to be conducted, and its place of business and principal office is to be located, in the City and County of New York.

In WITNESS WHEREOF we have made, signed, and acknowledged this Certificate, this 28th day of April, 1893.

WILLIAM H. WEBB.
CHAS. H. CRAMP.
H. T. GAUSE.
GEORGE E. WEED.
W. T. SAMPSON.
HORACE SEE.
F. L. FERNALD.
FRANCIS T. BOWLES.
W. L. CAPPS.
E. D. MORGAN.
GEORGE W. QUINTARD.
HARRINGTON PUTNAM.
J. W. MILLER.

City and County of New York, *ss:*

On this 28th day of April, 1893, before me personally appeared William H. Webb, Charles H. Cramp, H. Taylor Gause, George E. Weed, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, and Edwin D. Morgan, to me known and known to me to be the persons described in and who executed the foregoing certificate, and severally acknowledged to me that they executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

City and County of New York, *ss:*

On this 1st day of May, 1893, before me personally appeared George W. Quintard and Harrington Putnam, to me known and known to me to be the individuals described in and who executed the foregoing certificate, and they severally acknowledged to me that they executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

City and County of New York, *ss:*

On this 9th day of May, 1893, before me personally appeared Jacob W. Miller, to me known and known to me to be one of the individuals described in and who executed the foregoing certificate, and he duly acknowledged to me that he executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

(Endorsed.)

Upon reading the within Certificate for the Incorporation of the Society of Naval Architects and Marine Engineers, I hereby approve and consent to the incorporation thereof and the within Certificate and filing thereof, and direct that the same be filed in the office of the Clerk of the City and County of New York.

Dated New York, May 10, 1893.

Edwd. Patterson,
Justice of the Supreme Court in the State of New York in and for the City and County of New York.

CONSTITUTION AND BY-LAWS OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

Article I.

Name and Object.

1. The name of this Association shall be "The Society of Naval Architects and Marine Engineers."

2. Its object shall be the promotion of the art of shipbuilding, commercial and naval.

3. In furtherance of this object, annual meetings shall be held for the reading and discussion of appropriate papers and interchange of professional ideas, thus making it possible to combine the results of experience and research on the part of shipbuilders, marine engineers, naval officers, yachtsmen, and those skilled in producing the material from which ships are built and equipped.

Article II.

Membership.

1. The Society shall consist of Members, Associates, Juniors, Honorary Members and Honorary Associates.

2. *Members.*—(1) The class of Members shall consist exclusively of Naval Architects, Marine and Mechanical Engineers, including Professors of Naval Architecture or Mechanical Engineering in colleges of established reputation.

(2) A candidate of this class must be not less than twenty-five years of age and comply with the following regulations:—He shall submit to the Council a statement showing that he has been engaged in the practise of his profession, in a responsible capacity, for at least three years, and setting forth his grounds upon which he bases his claim to membership. This statement shall be signed by three Members, who shall certify to their personal knowledge of the candidate and approval of his statement.

(3) In the case of persons not American citizens, the signatures of three Members shall be required in confirmation of their personal knowledge of the candidate's scientific attainments.

(4) If three-fourths of the Members of the Council present are in favor of the admission of the candidate, his name shall be submitted to the members of the Society at the next meeting, the voting to be by ballot, should a ballot be demanded.

3. *Associates.*—(1) The class of Associates shall consist of all persons who, by profession, occupation, or scientific attainments, are qualified to discuss the qualities of a ship.

(2) Candidates for this class shall submit to the Council a written statement of their qualifications for membership. If considered by three-fourths of the Council present duly qualified for Associate membership, their names shall be submitted to the Society at its next meeting, to be voted upon by the Members and Associates, voting to be by ballot, should a ballot be demanded.

4. The proportion of votes for deciding the election of Members and Associates shall be at least four-fifths of the number recorded.

5. *Juniors.*—(1) The class of Juniors shall consist of graduates of technical schools of established reputation, or persons who have not less than two years' practical experience in marine engine works or shipyards.

(2) Candidates must be at least eighteen years of age and certify their intention to continue in the profession and become naval architects or marine engineers.

(3) Juniors shall be eligible for transfer to the class of Members after fulfilling the necessary conditions; when they are twenty-six years of age they shall be offered the option of being transferred to active or associate membership, if they duly qualify; but if they do not accept such offer, or do not qualify, they shall be dropped from the rolls of the Society.

(4) The admission of Juniors shall be by a favorable vote of three-fourths of the members of the Council present.

(5) Juniors shall have no voice in the government of the Society or admission of members.

6. *Honorary Members and Honorary Associates.*—The Council may elect Honorary Members and Honorary Associates, the total number not to exceed twenty-five. They shall be persons of acknowledged eminence in their profession upon whom the Council may see fit to confer an honorary distinction.

Article III.

Dues.

1. The entrance fees, payable on admission to the Society, shall be as follows:—

Members and Associates, ten dollars; Juniors, five dollars; Honorary Members and Honorary Associates, no fees.

2. The annual dues shall be as follows:—

Members and Associates, ten dollars; Juniors, five dollars; Honorary Members and Honorary Associates, no dues.

3. A member transferred from one grade to another shall pay the difference between the entrance fees of the two grades, and his annual dues shall be those of the grade to which transferred.

4. The annual contributions shall be payable in advance on the first day of January. The Secretary shall notify each member of the amount due for the ensuing year at the time of giving notice for the annual meeting. On election, each member shall pay his entrance fee and annual dues for the current year and be entitled to receive the proceedings of the annual meeting of the year during which he is elected.

5. Members and Associates can compound for all future dues and become Life Members and Life Associates, by making a single payment of two hundred dollars and signing an agreement to conform to any future amendments to the Constitution and By-Laws.

6. Members are entitled to no return of fees on severing their connection with the Society.

7. Any member whose dues are more than three months in arrears shall be notified by the Secretary. Should his dues become six months in arrears he shall be again notified by the Secretary and his rights as a member suspended. Should his dues become one year in arrears, the delinquent member shall forfeit his membership in the Society unless the Council may deem it expedient to extend the time of payment.

8. The Council may, in its discretion, temporarily suspend the annual payment of dues by any member whose circumstances have become such as to make such payment impossible, and may, under similar circumstances, remit the whole or a part of dues in arrears.

9. No name shall be entered on the rolls as Member, Associate or Junior, nor shall the privilege of membership be enjoyed until all dues shall have been paid; if the payment be delayed for more than six months from the date of election the same shall be void unless the Council otherwise direct.

10. (1) Should the expulsion of any member be judged expedient by five or more members, they must draw up and sign a proposal requesting such expulsion, delivering the same to the Secretary, to be laid before the Council.

(2) If the Council do not find reason to concur in the proposal, no entry thereof shall appear in the minutes, nor shall any public discussion thereon be permitted.

(3) If, however, the Council find the charges contained in the proposal for expulsion substantiated, the accused member shall be notified and given an opportunity to resign. If he avails himself of this privilege, no entry shall be made on the minutes nor public discussion of the case permitted; but if he declines to resign and offers no satisfactory explanation of the charge, the whole case shall be submitted to a special meeting of the Society.

(4) If two-thirds of the members at this special meeting (provided there be not less than twenty present) vote for expulsion, the chairman of the meeting shall cause the accused to be expelled from the Society, and direct the Secretary to notify the accused of this action.

Article IV.

Officers.

1. The officers of the Society shall consist of a President, Past Presidents, Honorary Vice-Presidents, twelve Vice-Presidents, twenty-four Members of Council and a Secretary and Treasurer.

2. Both Members and Associates are eligible for the offices of President, Vice-President, and Members of Council, but three-fourths of the Council shall be Members.

3. Prior to the date of the annual meeting of the Society of the year with which the term of the President expires, the Council shall nominate a condidate for the office of President, whose name shall be presented to the Society for election at the annual meeting. Any other candidate whose nomination, signed by at least sixty Members and Associates, shall have been submitted to the Secretary prior to the annual meeting shall also be presented. The candidate receiving the highest number of votes shall be the President for the ensuing three years. The first President under this rule shall be elected at the annual meeting in 1906 and his term of office shall begin January first, 1907. The President shall not be eligible for election as his own successor.

4. The term of office of the Vice-Presidents shall be three years. The Vice-Presidents whose terms by election now expire in 1911 and 1912 shall expire as of December 31, 1911; those whose terms now expire in 1913 and 1914 shall expire December 31, 1912; those whose terms now expire in 1915 and 1916 shall expire December 31, 1913. Beginning with the four Vice-Presidents elected for the term ending December 31, 1914, there shall be four Vice-Presidents elected each year to take the place of those whose terms expire. The Vice-Presidents to fill the vacancies occurring each year in any class shall be elected by the Council from their own membership. Retiring Vice-Presidents shall be eligible for re-election. Honorary Vice-Presidents shall be chosen from the list of Vice-Presidents who have had at least ten years service as Vice-President. They shall be chosen at the meeting of the Council next prior to the annual general meeting of the Society and must be the unanimous choice of all Members of Council present. Not more than two Vice-Presidents may be elected Honorary Vice-President in any one year.

5. The term of office of the Members of Council shall be three years. Prior to September 1st of each year the President shall appoint a Nominating Committee of five (Members and Associates both being eligible). This committee shall prepare a list of six Members and two Associates to fill the vacancies occurring in due course at the end of the year, and shall forward the same to the Secretary by September 1st. This list of names shall be mailed as soon as practicable after September 1st of each year to Members and Associates. The ballots shall be returned by mail to the Secretary and canvassed at the annual meeting. When the said list of names has been sent out by the Secretary, should there be a desire on the part of Members or Associates to suggest another list of candidates for the Council, any twenty Members and Associates may unite in submitting another list to the Secretary which shall also be sent out to the membership to be considered in connection with the list already sent. In case such additional nominations are made the six Members who receive the highest number of votes shall be declared elected Members of Council and the two Associates receiving the highest

number of votes shall be declared elected Associate Members of Council, in each case for a term of three years.

6. A vacancy in the office of President shall be filled by ballot by the Council from the list of Vice-Presidents until the end of the year in which it occurs. At the annual meeting of that year a new President shall be elected for three years in the manner prescribed in paragraph 3. A vacancy in the office of Member of Council shall be filled by the Council for the unexpired portion of the term of the Member or Associate causing the vacancy.

7. The Presidents, Past Presidents and Vice-Presidents shall be *ex-officio* Members of Council.

8. The Council may hold meetings, subject to the call of the President, as often as the interests of the Society may demand.

9. At all meetings of Council, five members shall constitute a quorum.

10. The Secretary and Treasurer shall be elected annually by the Council, but may be removed at any time by a majority vote of the Council after due notice has been given.

11. The Secretary must be a Member of the Society.

Article V.

Management.

1. The President shall have general supervision over affairs of the Society, appoint special committees, and preside at the annual general meetings. He shall be *ex-officio* member of all committees.

(2) In the absence of the President, the Vice-Presidents, in the order of seniority, shall preside and perform all the duties of the President.

2. The direct management of the Society shall be vested in an Executive Committee composed of five Members of Council elected annually by the Council, the President and Secretary of the Society being *ex-officio* members of the Committee. At least three of the five elective members of the Committee shall be Members of the Society.

3. The Executive Committee shall manage the affairs of the Society in conformity with the laws under which it is incorporated, and the provisions of the Constitution. It shall direct the investment and care of the funds of the Society; make appropriations for specific purposes; arrange for the reading and publication of professional papers under such regulations as the Council may, from time to time, prescribe; take measures to advance the interests of the Society, and generally direct its affairs.

4. The Executive Committee shall make an annual report to the Society, transmitting the report of the Secretary and Treasurer and of any special committee which may have been ordered.

5. The Secretary shall be the executive officer of the Society under the immediate direction of the President and Executive Committee.

(2) He shall prepare the business for the annual meetings and record the proceedings thereof.

(3) He shall be responsible for all expenditures and certify the accuracy of all bills or vouchers upon which money has been paid, and he shall conduct the correspondence of the Society and keep full records of the same.

6. The Treasurer shall see that all money due the Society is collected and carefully invested in such manner as the Executive Committee may direct. If considered advisable by the Council, the duties of Treasurer may be performed by the Secretary.

7. The accounts of the Secretary and Treasurer shall be audited annually by a special committee of three Members of the Council appointed by the President of the Society.

Article VI.

Meetings.

1. There shall be at least one annual general meeting of the Society for the reading and discussion of professional papers, election of officers for the ensuing year, and transaction of such other business as may be brought before it. The time and location of this meeting shall be determined by the Council at least three months prior to the date fixed.

2. Special meetings may be called by the Executive Committee at the request of twenty members, which request shall state the purpose of the meeting. The call for such meetings shall be issued ten days in advance, and shall state the purpose thereof. At these meetings, thirty members shall constitute a quorum.

3. The Society may adopt from time to time such rules as it may think proper for the order of business at its meetings.

4. Special meetings of the Executive Committee may be held at any time subject to the call of the Chairman; and four members shall constitute a quorum for the transaction of any business that may be properly brought before the Committee.

Article VII.

Amendments.

1. Proposed amendments to this Constitution must be reduced to writing and signed by not less than ten members. They shall be forwarded to the Secretary at least ten days before the annual general meeting, and shall be immediately forwarded to the Council for its consideration. If a majority of the Council approve the proposed amendment, it shall be presented to the Society at the next ensuing general meeting for discussion; if approved by two-thirds of the members present, voting by ballot, if a ballot be demanded, it shall be adopted.

INTRODUCTORY PROCEEDINGS.

NINETEENTH GENERAL MEETING OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

THURSDAY MORNING, NOVEMBER 16, 1911.

The Nineteenth Annual Meeting of the American Society of Naval Architects and Marine Engineers was held in the Engineering Societies Building, New York City, on Thursday and Friday, November 16 and 17, 1911.

President Stevenson Taylor called the meeting to order at 10.20 o'clock and said:

We will listen to the report of the Acting Secretary-Treasurer, which is also the Annual Report of the Council. Mr. Cox, Acting Secretary-Treasurer, will present the report.

The Acting Secretary-Treasurer presented the report, and in connection therewith said:

On the second sheet you will see a list of the members delinquent in their dues. This is a matter which is regrettable, and steps are being taken to impress upon the members who are delinquent the importance of coming forward with their dues, and any assistance that the members of the Society at large can give in this direction will be thankfully accepted.

The financial statement appears on the last three sheets of the report, and a summary of the statement shows a very satisfactory state of finances. Turning to the last sheet, it will be seen that the Society has practically no liabilities whatsoever, the items coming under the head of "Liabilities" merely being certain cash receipts that have been turned in and are applicable to next year's receipts; and the Society at the present time has a very substantial actual cash balance. Taking that, together with the fact that we have this large amount of outstanding dues, the greater portion of which can certainly be collected, it seems to indicate that the financial condition of the Society is very satisfactory.

REPORT OF ACTING SECRETARY-TREASURER.

NOVEMBER 10, 1911.

To the Council,
Society of Naval Architects and Marine Engineers.

GENTLEMEN: I have the honor to submit the following report showing the condition of the Society at the close of the fiscal year ended October 31, 1911.

The membership of the Society, November 1, 1911, was as follows:—

Class of Members.	Membership Nov. 1, 1910.	Elected November, 1910.	Promotions Associates to Members.	Deaths.	Resignations.	Suspensions.	Membership Nov. 1, 1911.
Members	489	35	+22	13	7	9	517
Associates	202	9	−22	3	10	13	163
Juniors	62	5	—	—	8	30	29
Life Members	5	2	—	—	—	—	7
Life Associates	4	—	—	—	—	—	4
Honorary Members	1	—	—	—	—	—	1
Honorary Associates	3	—	—	—	—	—	3
Totals	766	51	—	16	25	52	724

The following delinquencies exist in the payment of dues:

	No.	Amount.	Total.
For the year ended December 31, 1907:—			
Members	3	$30 00	
Associates	1	10 00	
			$40 00
For the year ended December 31, 1908:—			
Members	7	$70 00	
Associates	6	60 00	
Juniors	3	15 00	
			145 00
Carried forward			$185 00

Brought forward			$185.00
For the year ended December 31, 1909:—			
Members	14	$140 00	
Associates	12	120 00	
Juniors	7	35 00	
			295 00
For the year ended December 31, 1910:—			
Members	38	$380 00	
Associates	23	230 00	
Juniors	22	110 00	
			720 00
For the year ending December 31, 1911:—			
Members	143	$1,430 00	
Associates	64	640 00	
Juniors	40	200 00	
			2,270 00
Total outstanding dues October 31, 1911			$3,470 00

The following deaths and resignations have occurred during the past year:—

Deaths (13).

Members (10)—

William H. Allderdice.
Frederick C. Bowers.
Alexander E. Brown.
Randall T. Dickinson.
Jarvis B. Edson.
James J. Killilea.
Douglass G. Moore.
William Rowland.
Horace T. Sloan, Jr.
A. Cary Smith.

Associates (3)—

Calvin B. Orcutt.
Walter L. Pierce.
Howard Wood.

Resignations (25).

Members (7)—

Carlton B. Allen.
Carl George DeLaval.
William H. Hartt.
James A. Hargan.
William L. Tobey.
Morris M. Whitaker.
Rudolph Zirpel.

Associates (10)—

Elliott I. G. Andersen.
Edward B. Barry.
R. W. Berliner.
Leonard Martin Cox.
Franklin J. Drake.
W. A. Engeman.
Alonzo Gartley.
George H. Guy.
John F. Meigs.
George A. White.

Juniors (8)—

Emil Amandus Briner,
Jay D. Hammond.
Gilbert D. Martin.
Alexander B. Tappen.
Ernest Thunberg, Jr.
William Uzelmeier.
Henry C. Wright, Jr.
William L. Wallace.

FINANCIAL

RECEIPTS.

From November 1, 1910 to October 31, 1911, inclusive.

Entrance fees of new members for the year ending December 31, 1911:—		
Life Membership (2)	$400 00	
Members and Associates (42)	420 00	
Juniors (5)	25 00	
		$845 00
Dues for year ending December 31, 1911:—		
Members and Associates	$4,755 00	
Juniors	135 00	
		4,890 00
Dues for year ended December 31, 1910:—		
Members and Associates	$1,392 00	
Juniors	60 00	
		1,452 00
Dues for year ended December 31, 1909:—		
Members and Associates	$210 00	
Juniors	25 00	
		235 00
Dues for year ended December 31, 1908:—		
Members and Associates	$45 00	
Juniors	5 00	
		50 00
Membership dues paid in advance:—		
For the year ending December 31, 1912	$50 00	
For the year ending December 31, 1913	10 00	
		60 00
Sales of Publications:—		
Society transactions to members and dealers	$1,103 50	
Special editions of papers	342 99	
		1,446 49
Exchange on checks—members' dues		10 86
Banquet—annual meeting, 1910	$790 00	
Annual meeting, 1911	15 00	
		805 00
Interest:—		
On municipal bonds, City of New York	$175 00	
On bank balance, Franklin Trust Company	16 11	
		191 11
Bowles' Testimonial:—		
Excess of subscriptions		19 00
Loan:—		
Franklin Trust Company		700 00
Total receipts		$10,704 46
Balance, cash in bank and on hand, November 1, 1910		70 87
		$10,775 33

STATEMENT.

DISBURSEMENTS.

From November 1, 1910 to October 31, 1911, inclusive.

Publications:—		
Balance printing, Volume 17	$600.00	
Printing, Volume 18	3,655 47	
Miscellaneous printing	434 05	
Forwarding volumes, papers and membership year books	70 64	
Storage of volumes	106 08	
		$4,866 24
Rent of Safe Deposit Box, Franklin Trust Company		5 00
Expenses 17th annual banquet, November, 1910		858 30
Expenses 17th annual meeting, November, 1910, postage, programmes, etc		335 50
Expenses 18th annual meeting, November, 1911, postage, programmes, etc		133 50
Exchange on remittances members' dues		7 33
Salaries and clerical expenses		1,380 00
Audit of books and accounts to November 1, 1911		150 00
Rent of Society rooms		720 00
Office expenses, postage, stationery, etc		710 26
Loan paid:—		
Franklin Trust Company	$700 00	
Interest on loan	7 48	
		707 48
Total disbursements		$9,873 61
Balance, cash, October 31, 1911:—		
In Franklin Trust Company	$887 41	
On hand	14 31	
		901 72
		$10,775 33

Statement of Resources and Liabilities.

RESOURCES.

Membership dues from members after deducting for deaths and resignations ($195.00) and for doubtful accounts ($870.00)	$2,405 00
Dues from dealers for volumes	784 00
Accrued interest, municipal bonds	315 00
Municipal bonds, at cost	12,560 00
Office furniture and equipment, at 10 per cent. reduction from cost	1,235 55
Publications on hand, at 25 per cent. reduction from cost	5,890 00
Cash on deposit, Franklin Trust Company	887 41
Cash on hand	14 31
Total resources	$24,091 36

LIABILITIES.

Membership dues paid in advance	$60 00
Paid in advance, 1911 banquet	15 00
Paid in advance for volume	10 00
Total liabilities	85 00
Society's present worth, October 31, 1911	24,006 36
	$24,091 36

The financial statements have been verified by the Universal Audit Company of New York.

Respectfully submitted,

DANIEL H. COX,
Acting Secretary-Treasurer.

THE PRESIDENT:—You have heard the report of the Acting Secretary-Treasurer. What is your pleasure?

Mr. LEWIS NIXON:—I move that the report of the Acting Secretary-Treasurer be accepted and placed on file.

(The motion was duly seconded and carried.)

THE PRESIDENT:—Gentlemen, please rise in memory of those who have died during the past year, while the Secretary reads the names.

(The Secretary read the list of deceased members, all of the gentlemen in the room standing during the reading of the names.)

THE PRESIDENT:—It is now my pleasure to read to you the names of those who were elected Members of Council and Associate Members of Council. As members of Council the following were elected: C. H. Peabody, F. L. Dubosque, H. C. Sadler, D. H. Cox, R. M. Watt and H. L. Ferguson. Associate Members of Council, H. L. Aldrich and A. P. Niblack. H. D. Goulder was elected to fill the vacancy caused by the death of Calvin B. Orcutt. These elections are to fill vacancies in Council for term expiring December 31, 1914.

It is with great regret that I announce to you that our Secretary-Treasurer for eight years, Mr. William J. Baxter, has declined reelection on account of his ill health. You will remember that he was stricken last summer, and while he writes that he is recovering, he thinks it better to decline a reelection. I will read you part of his letter:

"My health is now improving, but as it is very improbable that my next duty will be in New York, and as it is of vital importance that the Secretary should be there, I feel that it is my duty to the Society to make room for some one else.

"My Society work was more than pleasant, it was enjoyable, and I shall always be proud of the confidence and good will it has always shown me.

"Please express to the members my great regret that I cannot be with them this year, and my hope that their interest in the Society's work will continue to grow even more rapidly than it has in the past.

"Very cordially,
"W. J. BAXTER."

A Committee was appointed by the Council to prepare suitable resolutions in recognition of the services of Mr. Baxter, and before the meeting closes those resolutions will be presented to you. Recognizing the situation mentioned in this letter, the Council elected Mr. Daniel H. Cox, whom I now have the pleasure of introducing to you as Secretary-Treasurer of the Society of Naval Architects and Marine Engineers, his term of office commencing January 1st, next. (Applause.)

The Secretary will read the list of the candidates for membership in the Society, who have been passed by the members of the Council, and whose names are submitted to you for approval or disapproval.

The Secretary read the names of those passed by the Council for membership in the Society, as follows:

Members (15).

Gardner Cornett, Vice-President, American Steam Gauge & Valve Mfg. Co., 30 Church Street., New York, N. Y.

Stephen A. Gardner, Jr., Engineer, Electric Boat Co., Groton, Mass.

Joseph E. Henderson, Ship & Engine Builder, Ft. Montgomery Street., Baltimore, Md.

Arthur P. Homer, Naval Architect and Engineer, 88 Broad Street, Boston, Mass.

James Kennedy, Supt. Marine Dept., J. M. Guffey Petroleum Co., 21 State Street, New York, N. Y.

Lewis B. Doane, Chief Engine Draftsman, Electric Boat Co., Groton, Conn.

George H. Kochersperger, Asst. to Genl. Supt., Wm. Cramp & Sons Ship & Engine Building Co., Philadelphia.

Charles S. Linch, Consulting Engineer & Naval Architect, Bordentown, N. J.

Richard A. McCabe, Asst. Supt. Engineer, U. S. A. Transport Service, Pier 12, San Francisco, Cal.

George A. Orrok, Mechanical Engineer, N. Y. Edison Co., 55 Duane Street, New York, N. Y.

Ernest O. Patterson, Inspector in Ship Construction, U. S. Engineer Dept., Dubuque Boat & Boiler Wks., Dubuque, Iowa.

Linden Stuart, Ship & Engineer Surveyor, American Bitumastic Enamels Co., 109 Broad Street, New York, N. Y.

William Newman, Works Manager, Polson Iron Works, 125½ Sherburne Street, Toronto, Canada.

Herbert B. Saunders, Marine Surveyor, 15 Whitehall Street, New York, N. Y.

Theron S. Atwater, 45 Wall Street, New York, N. Y.

Associates (7).

Adolphe E. Borie, Vice-President, Taylor Iron & Steel Co., High Bridge, N. J.

Robert A. C. Smith, President, American Mail Steamship Co., 100 Broadway, N. Y.

Hans R. Morch, Draftsman, Fore River S. B. Co., Quincy, Mass.

Charles A. Schafer, Computer, Scientific Dept., Electric Boat Co., Quincy, Mass.

William Shaw, Chief Engineer, S. Y. Vanadis, 103 Belevue Avenue, Upper Montclair, N. J.

Robert S. Haydock, Engineer, Mosher Water Tube Boiler Co., 30 Church Street, New York, N. Y.

John W. Anderson, Leading Draftsman, Electric Boat Co., Groton, Conn.

Juniors (4).

Gordon G. Holbrook, Asst. in Naval Architecture Dept., Massachusetts Institute of Technology, Boston, Mass.

Robert L. Hogan, Draftsman, Fore River S. B. Co., Quincy, Mass.

Ralph T. Hanson, Asst. Naval Constructor, U. S. N., Navy Yard, Boston, Mass.

Jerome C. Hunsaker, Asst. Naval Constructor, U. S. N., Navy Yard, Boston, Mass.

Juniors transferred to Members (8).

Carl A. Bergstrom, Leading Draftsman, Fore River S. B. Co., Quincy, Mass.

Frederick A. Hunnewell, Draftsman in Charge Suptg. Constructor, N. Y. Shipbuilding Co., Camden, N. J.

Ambrose M. Merrill, Draftsman, Hull Division, Navy Yard, New York.

A. Loring Swasey, President Swasey, Raymond & Page Inc., Colonial Bldg., Boston, Mass.

Howard C. Towle, Leading Draftsman, N. Y. Shipbuilding Co., Camden, N. J.

Nathaniel A. White, Draftsman in Charge, Estimating Dept., Hull Division, Navy Yard, Philadelphia.

Ernest Fils, Chief Draftsman, Robins Dry-Dock & Repair Co., Erie Basin, Brooklyn.

Eads Johnson, Consulting Engineer, 30 Church Street, New York.

Juniors transferred to Associate (4).

Frank H. Crane, President and Manager, Townsend & Moore Engineering Works, Erie Basin, Brooklyn, N. Y.

Robert C. Simpson, Draftsman, New London Ship & Engine Co., Groton, Conn.

Constantine D. Callahan, Naval Architect & Engineer, 1811 Center Street, San Pedro, Cal.

William J. J. Young, Draftsman, Suptg. Constructor's Office, Fore River S. B. Co., Quincy, Mass.

The President:—According to the Constitution, a ballot must be taken, if demanded. Do you desire a ballot to be taken? As no ballot seems to be demanded, I ask your pleasure as to the election of the candidates whose names have been read to you.

Mr. Lewis Nixon:—I move that they be elected to the various grades of membership stated by the Secretary.

(The motion was seconded and carried.)

The President:—The gentlemen named are now members of the Society, of the grades of membership specified.

With a great deal of pleasure I request Sir William Henry White and Past President Bowles to take seats on the platform. (Applause.)

The next business in order is the annual address of the President.

President Taylor then read his address, which was greeted with loud applause.

PRESIDENT'S ADDRESS.

GENTLEMEN:—As you will have already observed the papers to be read and discussed at this Nineteenth Meeting of The Society of Naval Architects and Marine Engineers are unusually numerous and unusually interesting. So much so that the two days allotted to our Meeting will be all too brief for the consideration deserved. You will therefore be pleased by my prevailing thought at this moment that brevity is the soul of discourse as well as of wit.

You will note on reading the report of the Acting Secretary-Treasurer that the condition of the Society is quite satisfactory.

I desire again to call your attention to the advantages of life membership, additions to which strengthens our finances.

Concerning the one subject that probably is nearer to us as Naval Architects and Marine Engineers than any other—that of the American merchant marine—I have but little to say. We seem to be no nearer the establishment of such service between this and foreign countries than we were a year ago, and we will be no nearer so long as the friends of such enterprise have so many remedies for the situation. I still believe that some time the many views now held by those who would advance the prospects of our Merchant Marine, will be modified in such a way that finally there will be a concentration on one idea, so supported by public opinion that the desired result will be attained.

There have been published various reports of exceeding activity on our shipyards which to the ordinary reader would indicate that there is no need of any legislation assisting the promotion of the merchant marine. Inquiries were made of all of the large shipyards on the Great Lakes and Atlantic Seaboard and without taking into account the inland river steamers, tugs, and barges, there were found to be in the twelve main shipyards of the Lakes and Atlantic thirty-three (33) vessels for the United States Government, having a displacement of one hundred and sixty-seven thousand two hundred (167,200) tons, and five (5) for other Governments having a displacement of about sixty thousand two hundred (60,200) tons; and for coastwise merchant freight service thirteen (13) steamers having an approximate displacement of eighty thousand (80,000) tons. Excepting through interviews with those in authority published from time to time I do not know what the future policy of the Government as to the Navy may be, but if that support be taken from our shipyards, the figures given before show a very moderate amount of work indeed for so many plants valuable in the funds expended therein and in the great ability of their designers and executive forces. Advocate as I am of a supreme Navy I still more advocate the need of a large and important merchant marine.

I note with pleasure in the replies made to the inquiries before mentioned the hopeful spirit which prevails as to the future and I quote from one with emphasis: "it is time that some action should be taken on the part of the United States Govern-

ment in favor of legislation which will be favorable to the American merchant marine. We have all sorts of things projected in the political arena of this country of late but the question of legislation in favor of building up the merchant marine should enter largely into our politics and be made a paramount issue. No healthier political agitation could come to this country and result in greater benefit to the people of the United States."

The completion of the Panama Canal is expected to increase the demand for Coastwise Steamships and without any doubt this should be the case, but we insist that all inherent rights of the United States people who are paying for this great enterprise shall be preserved and held inviolable; and that any treaty that can be conceivably construed to interfere with this position shall be abrogated. I commend to your careful consideration one of the papers on this subject which will be presented at this meeting.

Permit me to quote again from another reply what seems to be a valuable hint. "It now looks as though the coast yards would have plenty of inquiries for vessels of good size. Let us hope that good horse sense will prevail so they may secure prices which will give them a profit. They certainly are entitled to it." In other words, inject into your future competition the word "reasonable" a valuable addition to recent legal phraseology.

About noon on a bright clear day last July, I was crossing Spithead from South Sea to the Isle of Wight. Our little paddle steamer was held up midway and directly before us passed out to sea the great British Naval Fleet that had been assembled the week before for review by the newly crowned King, George V. I had seen the Coronation Processions in London and had been deeply impressed by the stately dignified ceremonials. They made me feel as though there had passed before my eyes the historical events of centuries; but I had missed the great Royal Naval Review, prominent in which our own flag had been gallantly borne by the Delaware. The Royal Review was of battleships, cruisers, and other men-of-war at anchor, gayly decorated for the occasion and indeed it must have been a grand sight. But to me on the little paddle boat, this same Naval Fleet proceeding to sea practically in double column, ready for business, moving forward with solemn resistless force presented a far more effective sight than when dressed in gala array at anchor.

When the last ship had passed, there stretched within our vision a huge gray crescent of men-of-war nearly fifteen miles long. Such a display of majesty and power combined I had never before witnessed and the thought came—what destruction, what carnage would be possible were this great fleet to be assembled, say off Sandy Hook, with hostile intent.

To relieve your minds let me say that not for one infinitesimal part of time did I fear the ultimate outcome; but the thought of the immediate possible outcome was appalling.

A few days ago, our own naval fleet was anchored for several miles along our peaceful Hudson; and they in turn passed out to sea under review of the President of the United States and they looked good to me. I am proud of our Navy and

proud of The Society of Naval Architects and Marine Engineers upon whose roll are numbered those who are responsible for the design and construction of this magnificient fleet.

Possibly, indeed I may say probably, the much desired principle of Arbitration will do away with the need of these monster fleets but as I gazed at our fleet sailing down New York Bay and I recalled the sailing of the great British Fleet out into the English Channel it seemed to me that combined for Right and Justice, backed by the respective Governments they would form an unconquerable power for Peace throughout the world.

This Society was invited by The Institution of Naval Architects (of Great Britain) to be present in 1910 at its Jubilee Meeting celebrating the fiftieth anniversary of its incorporation.

You will remember that the lamented death of King Edward VII caused this event to be postponed until this year when the invitiation was renewed.

About twenty-five of your officers and members were fortunate enough to accept the kind invitation and to be present at the meetings and attendant festivities commencing July third with a preliminary reception by the president of the institution, The Most Honorable the Marquis of Bristol R. N., Lady Bristol and the Council, followed by the formal opening of the meeting by the Honorary President, H. R. H. the Duke of Connaught K. G., and finishing at the end of the week with a visit to Windsor Castle by command of His Majesty the King.

From beginning to the end of this Jubilee there was a splendid program conceived with infinite courtesy and care for the pleasure of all and executed with admirable precision.

Besides the special entertainments prepared by the institution there were notable receptions given by His Majesty's Government, by Lord and Lady Brassey, by American Ambassador and Mrs. Whitelaw Reid and by Lloyds' Registry of British and Foreign Shipping.

Altogether it was a memorable occasion never to be forgotten by those who participated.

It is with especial gratification that we note the presence at this meeting of our distinguished Honorary Member, Sir William Henry White, K. C. B., etc., formerly the Naval Constructor in Chief of the British Empire. He is responsible for many superexcellent designs of the war vessels of the British Navy and some of those of other navies, as well as for the fastest merchant vessel in the world, the almost perfect performance of which will be mentioned today in his paper.

Under his guidance some of our own Naval Constructors at the beginning of our new navy obtained their special education. To him many engineers, civil, mechanical and naval, are greatly indebted for innumerable courtesies in his own land.

He has received abroad and in this country many well deserved honors and has now again come to receive the John Fritz Medal bestowed upon him by its board of award for his notable achievements in naval architecture.

In your behalf I bid him thrice welcome and tender our best wishes for a long continuance of a busy and useful life.

THE PRESIDENT:—The reading of the papers is now in order. I take great pleasure in presenting to you Sir William Henry White, who will read his paper, which is first on our program, "On The Maximum Dimensions of Ships."

SIR WILLIAM H. WHITE, *Honarary Member:*—Mr. President and Gentlemen, before I read this paper in abstract, I should like to have the opportunity of thanking the Society for the great honor that was done me many years ago in electing me an honorary member. Not long after that action was taken, my health broke down under the stress of work, but the kindness which was shown me by the President and members of this Society—the President at that time being my friend and former pupil, Admiral Bowles—I shall never forget.

This is the first time that I have been able to attend a meeting of the Society, and I wish to take the opportunity, sir, of saying in my own words what I have written many years ago, that I am and ever shall remain your grateful debtor.

It will be for the convenience of the meeting, as this paper has been written mainly to provoke discussion, if I indicate its principal points as I go along, in order to save time, and do not attempt to read the paper *in extenso.* I should explain that it was written under difficult circumstances, mainly in mid-Atlantic, and in weather when the only means I had of writing was to use a pencil, because the movements of the ship were violent. It was revised in Winnipeg a few days ago; if there are any traces of haste in its composition, I hope you will excuse them because of the circumstances under which the paper was prepared.

Sir William Henry White then presented the paper in abstract, making the following comments, which do not appear in the paper:

In paragraph I, after "Always will be promoted by increased dimensions"—that is, when the ships are under way and at sea people often forget that a large part of the time of service of ships is spent in port, and not under way. That is a point to which I draw attention later on.

Paragraph II, after the words "and 20 exceeded 15,000 tons"—Facts of that nature are not recognized in these discussions as a rule, and they require to be.

Also in paragraph II, after "Similarly influenced all mercantile marines"—I need not trouble you with the facts, but I have got them here, and they can be found in statistical statements of shipping.

In paragraph III, after "Were not improved upon"—I can remember the time when we were up against that difficulty of increasing the dimensions of wood-hulled ships. As a boy at Devenport I have been on board the Orlando screw-frigate, 300 feet long, 5,600 tons displacement and 4,000 horse-power, wood built. The attachments of the stern to the rudder post and stern post were continually breaking when full engine power was developed, and the ship herself could not keep her form. That condition of things no longer affects us as naval architects.

I do not say a word against building bigger ships if they can be worked and make a profit; but to-day we are not considering the commercial side of shipbuilding, but the commercial side of shipowning.

In paragraph IV, after the words "Has been relatively small"—I need not say a word to this assemblage about what the disproportionate increase has been or what it has involved. Many of the largest ships now in service cannot load to the draught to which they are capable of being laden safely, and a singular result of that fact is that in published statistical statements of ships one sometimes sees recorded load-displacements which are only obtainable if the ships are taken out to sea into deep water and laden there. Published displacements do not always correspond to working conditions of draught and very often laymen have been led thereby to form singular conclusions. In one case the President of a great English Engineering Society named the length, breadth and depth of a ship, and associated with these dimensions a displacement which was greater than the ship would have had, if she had been laden down to 40 feet, that is, to her statutory maximum draught, whereas in practice the ship was only laden to about 30 feet. The result was ridiculous, but the speaker had accepted figures given to him by shipbuilders without proper explanation.

Paragraph VI. The Kiel Canal is a case in point. The German Government is spending $55,000,000 on reconstructing that canal. The main purpose underlying that work is strategical, to enable the German fleet to move speedily and safely from the Baltic to the North Sea. I presume the construction of the Panama Canal is also not altogether without relation to strategical advantages which will result therefrom. Considerations such as these are special; they affect the whole nation, and have not to do only with the welfare or working of the mercantile marine, considered as a money-making proposition.

As to the limit of depth of water likely to be reached, I am of opinion that it is improbable that it will exceed 40 feet in most of the ports of the world. In British seaports we have a great advantage in the considerable rise of tide which occurs. The statements given in the paper, as to actual depth, must be associated with that condition, as, at high water, we enjoy a much greater depth than would be true in many other parts of the world.

Paragraph VII. These decisions represent conclusions reached by the various authorities after conference with those men who are supposed to have the right to give an opinion as to probable increase in dimensions of ships during, say, the next quarter of a century. I have been myself repeatedly consulted by these authorities and my recommendations have had an influence on the work undertaken in harbors, docks, and approach channels.

In paragraph IX, after "caution is required"—I dare say some of you have seen what may happen with an almost imperceptible velocity of approach, when one of these great ships strikes against some other ship or the wharf. We have had cases in England where attempts to get these long ships into the dock entrances, under tidal conditions which were unfavorable to the ship. In one case the

Mauretania was being taken into an entrance on the Mersey, and her stern was in a current moving in one direction, and her bow was in an eddy moving in another direction. When you stretch over 800 to 900 feet that may easily happen as you approach the shore, and it is not a negligible condition at all. You cannot have these huge ships, which must be moved very slowly in those conditions, without having considerable risk and the need of great caution. And then that is not all—you must have in connection with ships of these dimensions the occupancy of a great space or the freedom for them to move in a great area which detracts from the use by other ships of these areas, and in most harbors of the world that is not a negligible quantity.

Paragraph X. After the words "extended widely"—On the voyage out to Montreal I had the good fortune to travel with one of the great English shipowners, interested in all classes of ships. I said to him: "Taking things as they are at the present time, what do you consider to be the most useful size of ship; what do you think is the upper limit of draught of water that will be commonly adopted?" His answer was, "About 7,000 tons dead weight cargo capacity and about 24 feet laden draught of water." From the point of view I have just mentioned, this appears to be a reasonable conclusion.

Paragraph X. After "is frequently 4 to 5 feet"—At the Review at Spithead, to which the President referred in his opening address, there were vessels whose normal draught of water is given in published official tables as 26 to 27 feet, but I personally observed they were drawing 31 feet.

Some years ago warships of the United States Navy were always designed to have relatively shallow draught. Admiral Bowles must have found that restriction not altogether comfortable; but the condition was imposed upon him as essential to the service. In modern warships of the United States Navy the draught has been very much increased, and no doubt there is good reason for it. If we could hear why the change has been made, it would be very interesting.

There are some harbors which have been primarily constructed to serve as Naval bases into which many recently built British warships cannot go at all when deep-laden; and there are ports of these harbors. There are places where the ships cannot take shelter, although they were constructed at enormous cost for the purpose of sheltering warships. That is not a satisfactory condition of affairs and has resulted from increase in draught of the modern ships. This question of warship construction must be considered from the standpoint of the harbor engineer and owner—the places of shelter and supply—as well as from the shipowner's standpoint. These considerations will have marked effect whenever war happens, which, I pray God most earnestly may not occur. Ships of great draught will necessarily have their field of operations restricted and their ports of shelter and repair will be few. It is impossible that it can be otherwise, and the restriction may have serious consequences.

Paragraph XI. After "due to large size in passenger steamships"—The fact is as stated, although it does not seem very reasonable; there is a great attraction

for many people to take passage in the "biggest ships afloat." In regard to the maintenance of speed in rough water, I have on other occasions pointed out what seems to me to be the paramount consideration, viz., that the maintenance of speed at sea is chiefly dependent upon the relative size of the ship and the waves, and particularly their lengths. It is strange to note how little regard has hitherto been paid to the considerations to which I have drawn attention in the paper. Because ships have been made bigger, there is no reason to anticipate that waves will become larger and larger than in the past. The waves of the Atlantic remain what Dr. Scoresby discovered them to be sixty or seventy years ago. The facts which I put together more than thirty years ago in my "Manual of Naval Architecture" in regard to ocean waves are substantially accepted still after most thorough and repeated investigation in recent years. Attention is invited to the detailed statement made at the bottom of page 10 and top of page 11 of my paper, as to the actual performances of the Mauretania, a ship in which I have a considerable personal interest, but which is mentioned simply as a typical case. If after reading that summary any one will assert that for the purpose of securing regularity of Trans-Atlantic passages it is necessary to make bigger ships, I cannot argue further with him, but I must leave him alone. It seems to me the argument in this paper is unanswerable.

Another consideration which is often overlooked, although it applies to all classes of ships is this—the limit of speed at which a ship at sea can be driven—when one passes, say, from the torpedo boat destroyer up to a ship as large as the Mauretania—is not determined by the size of the ship, but rather by the fact that the danger of having the navigating position or the fittings destroyed by the blows of the sea is greatly increased if vessels are driven at a high rate of speed through heavy seas. This matter was forced on my attention nearly twenty years ago in the days when I designed the first torpedo boat destroyers. The cry for higher speeds was continually being raised, but it did not come from the men serving in destroyers, and it was a fallacy, because the higher speed asked for could not be utilized one day out of ten, even in the English Channel. It was only in dead-smooth water that the designed speeds could be utilized. Last year, the Captain of the Lusitania, a most experienced officer, said to me: "Since I have commanded this ship I have realized more than ever I did before that although a big ship may be driven at high speed in almost any sea, it is not worth doing if it involves the risk of green seas coming as high as the navigating station and of the pilot house being swept away." In the navigation of ships of any size, there must come a time when the captain, if he is a sensible, wise man, will not incur risks which are inevitable if a ship is driven hard against a heavy sea. Some people appear to believe if ships were made a thousand feet long that risk would disappear, but nothing of the kind could happen. Experienced seamen confirm what I say. What I have stated on the lower half of page 11 is also confirmed by experience. One need not make a ship large in order that she may be steady. One of the steadiest ships I have known was the cruiser Inconstant, although she was of less

than 6,000 tons displacement. In the Bay of Biscay I have seen a passenger steamer of only 10,000 tons remain practically upright while waves 30 feet high (from hollow to crest), were approaching her nearly broadside-on. It is not size, as we know, that makes a ship steady. Some of the largest warships in the world are notoriously unsteady as gun platforms. These ships have been made stiff, for other reasons, and consequently have short periods of oscillation, so that in ordinary conditions of seaway, they are not so steady as ships which are of smaller size yet have longer periods. Mere size is not necessary to good behavior at sea.

Paragraph XII. The facts as to the cost of Trans-Atlantic steamers from 1874 onward, there given, are of interest, and so is the summary of what was said a few years ago by a special committee appointed by the British Government to consider the question of subventioning fast cruisers. The action taken by the British Government, with the sanction of Parliament, when the Lusitania and the Mauretania were built, commanded general approval and there is still a feeling that the money is well spent.

According to the best information published we may take it that $7,500,000 is about the cost of the great Trans-Atlantic liners now in service, and there are other ships building which will probably cost about $8,750,000. The question is—What is the chance of these vessels earning a dividend? As an outsider I do not question the wisdom of decisions which have been reached by gentlemen of great experience in commercial life who have authorized the construction of these great ships. They are convinced, no doubt, that on the whole it was right for them to have the largest ships; but it is noteworthy that they have not gone in, also, for the fastest ships. There has been a limitation in speed and power as compared with the Lusitania and Mauretania. The Olympic has made, as you know, an average sea speed of about 21 knots, across the Atlantic. The average for the Mauretania has been 25.5 knots, and that excess of 4.5 knots represents a considerable increase of engine power and coal. The new German ships are to attain about 22 knots, and the Aquitania of the Cunard Line, is to reach 23 knots, according to report.

One matter treated at length in the paper is of great importance. Recent types, particularly the Olympic and the Titanic are really developments of the "intermediate" type of Trans-Atlantic steamer in which great passenger accommodation is associated with large dead weight cargo capacity. Expenditure on these ships however has reached or exceeded that incurred on their swifter predecessors of which I have spoken. One wonders what would be the net effect on earning power if an attempt were made to utilize the large cargo capacity of these vessels! It seems obvious that with such a great capital expenditure on a ship a quick "turn round" in port is essential to commercial success. It is equally obvious that if a huge amount of dead weight cargo is to be embarked at the port of departure and discharged at the terminal port, the vessel will be bound to remain in port for a considerably longer time than would be necessary simply if only passengers and a smaller cargo were carried As a matter of fact the schedule of

the great Cunard steamships was varied after a short time in order to diminish the time spent in port. It is true of all transportation, that the means of transportation must be utilized as fully as possible and loaded and discharged as quickly as possible if the best results are to be secured. Any increase in the periods during which the capital invested is non-productive, must prejudicially affect the net earnings. If high speed is to be obtained, knowing as we now do, what size of ship will secure practically regular passages across the Atlantic, it would appear that the best results will be obtained by the construction of what are called "express" steamers for passenger service. Time will show whether or not passengers think the advantage of a very quick traverse of the Atlantic a sufficient set-off against the other advantages which may be obtained in ships of less speed and greater carrying capacity.

Passing to warships, I have recapitulated toward the close of my paper what I said last year in my "Notes on the Armament of Battleships." These statements of mine, have been set down in quite cold blood, and I may be held fully responsible for them by critics. I may be wrong, but I have stated what I believed to be true, and I am prepared to maintain this doctrine against all comers to the best of my ability.

Sir William Henry White then completed the reading of the paper as printed, and at its conclusion there was loud applause.

ON THE MAXIMUM DIMENSIONS OF SHIPS.

By Sir William H. White, K. C. B., F. R. S., D. Sc., LL. D., D. Eng., Honorary Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

It has been thought desirable, during the present meetings, to initiate a discussion on probable growth in dimensions of ships, and I have been requested to introduce the subject. Having given close attention thereto for many years I have acceded to this request, and have prepared the following notes which may serve as a basis for discussion, although they do not profess to cover the whole ground which may be discussed.

The subject is undoubtedly important; it has an interest for naval architects, shipowners, dock and harbor authorities, travelers, and all classes of engineers. What seem to be chiefly needed are reasoned replies to certain questions:

1. Is it probable that the dimensions of ships will continue to grow at the rapid rate which has prevailed in recent years?

2. Will an upper limit to the sizes of ships be reached?

3. What considerations, if any, are likely to determine such a limit, for either merchant ships or warships?

Facts and figures relating to the wonderful growth in dimensions of ships are necessarily familiar to members of this Society. Since wood ceased to be the chief material for shipbuilding and steam began to supersede sail-power as the means of propulsion—say about sixty years ago—there has been a complete revolution in the design and construction of ships and an increase in size and speed which was undreamt of by our predecessors. Without attempting any detailed recapitulation of well-known facts, attention may be drawn to the circumstance that since the present century began the rate of growth in dimensions has been much accelerated. This will be seen from the two tables appended. In the first is summarized progress made in the sizes and speeds of Trans-Atlantic steamships during the latter half of the nineteenth century; it also enables progress during that period to be compared with corresponding progress during the last ten years. Table II deals similarly with armored warships. In view of the greatly accelerated rate of increase in dimensions which has occurred during the present century and is indicated by these tables, one may well ask, Whereunto will this thing grow?

In endeavoring to answer that question some persons resort to simple graphic methods. Dates of construction are used as abscissæ, and lengths (or tonnages) of ships employed as ordinates. On these data curves have been constructed, whose production, in a tentative fashion, is expected to furnish some indication of what will probably be the dimensions of the largest ships say twenty or thirty years hence. Personally I have no great confidence in this method. It has no scientific basis, it rests upon an assumption that materials and methods of construction, as well as systems of propulsion will remain practically unaltered during the period under consideration; and it presumes that the law of growth will hold continuously. It may be replied by those who favor the method, that it has answered fairly well so far; and that therefore it may be further employed with advantage. In my judgment, it is necessary to take a broader and more scientific view of the problem if a reasonably approximate solution is to be found. The means ought not to be altogether lacking for reaching a fairly approximate solution, if the conditions of the past and the outlook for the future are carefully considered. The case is not one for treatment by simple "rule of thumb" or more or less arbitrary extension of curves such as have been described; it requires an application of scientific analysis to past experience, and when this has been done the forecast based upon such analysis must necessarily be open to question, and may be falsified by subsequent events. In these circumstances caution is necessary and differences of opinion are justifiable.

Probably the most useful procedure will be to make a detailed statement of facts and principles which will, for the most part, command general assent; and in doing so it may not be out of place for me to state my own conclusions on points of controversy.

I. It will be agreed that the law of growth in dimensions has operated hitherto on all classes of ships and that its action has on the whole been beneficial. Members of this Society treat as axiomatic the statement that economy in propulsion and over-sea transport has been and always will be promoted by increased dimensions. The actual influence of such an increase has, in many cases, been masked or made less obvious by concurrent changes in other factors and features of ship-construction, but it has been none the less felt. Stronger materials of construction have been made available; more efficient types of machinery and propellers have been devised; higher steam-pressures have led to greater fuel economy, and higher rates of revolution have favored relatively lighter propelling apparatus. But after each such improvement has been introduced and utilized, the law of growth in dimensions has inevitably reasserted its claims on naval architects, and been again brought into operation in order to secure still further advantage in

respect of speed, carrying power, or other features of ship design. Successive vessels belonging to each and every class have been made larger than their predecessors.

Excellent illustrations of this general law may be found in the development of the smaller classes of war vessels during the last twenty years. In 1892, as Director of Naval Construction, I prepared the first design for so-called "torpedo boat destroyers" of which so much has since been heard. For the services then contemplated the dimensions thought most suitable were: length, 180 feet; breadth, 18 to 19 feet; displacement about 250 tons. The speed on trial was fixed at 26 to 27 knots, and this was sufficient for the purpose the vessels were designed to serve, viz., the destruction of then existing torpedo boats, which were of smaller size and less speed. At that date locomotive boilers were in general use for torpedo vessels, although water-tube boilers were coming into prominence. Marine steam turbines were not known, and quick-running reciprocating engines were necessarily employed. Our knowledge of screw propellers driven at rapid rates of revolution was much less than at present. Oil fuel was not a practical proposition. Mild steel was the best material available. During the last nineteen years the destroyer type has been developed in size and speed and although the name has been retained, the services for which later vessels have been designed, have not been limited to or even principally concerned with torpedo boat destruction. In fact the latest vessels in size and armament have grown into practical identity with the seagoing torpedo gunboats (Sharpshooters) which I designed in 1887–8 for the Royal Navy as the smallest self-supporting ocean going type. In speed the later vessels are much superior to torpedo gunboats of earlier date, and this has been made possible by the use of steam turbines, water-tube boilers, oil fuel, stronger steel and other improvements. There is even now a considerable diversity of opinion as to the value of exceptionally high speed in the type; but in all cases the law of increase in dimensions has prevailed, and vessels classed as destroyers—really seagoing torpedo gunboats—range in speed from 26 to 35 knots, the largest having displacements of about 1,000 tons.

Submarines also furnish illustrations of the working of that law. Boats of the Holland type adopted at the beginning of the century by the United States Navy, and soon after adopted for the British Navy, were of small dimensions—63 feet in length and of 120 tons displacement when submerged, the surface speed being 10 knots. By successive steps British submarines have been increased in size and speed, the latest examples, according to published reports, being nearly 180 feet long, 800 to 850 tons displacement, and 15 to 16 knots speed. In the United States similar growth in size and

speed has taken place. In France the largest submarines of 1901 were about 135 feet long, 200 tons, and 12 to 13 knots speed; vessels now building are 240 feet long, of 1,000 tons displacement when submerged, and the estimated surface speed is 18 to 20 knots.

The same general law has been at work in the mercantile marine. For each class the average size of ship has been increased, and the fact is apparent in every statistical "Return" of the movements of shipping. In 1860 the average gross tonnage of ships (exceeding 100 tons) on the Register of British Shipping was 340 tons; in 1870, 580 tons; in 1880, 1,250 tons; in 1890, 1,570 tons; in 1902, 2,200 tons. Since the Suez Canal was opened the average size of the vessels passing through it has grown steadily; the same may be said of the vessels passing through the Sault Ste. Marie Canal. Every "Return" of ships entering and leaving the great ports of the world tells the same tale of growth in dimensions and tonnage. Each annual statement of shipbuilding throughout the world furnishes an illustration of the working of this law. Many small ships continue to be built but there is an universal upward tendency in size.

II. It must be noted, however, that—notwithstanding the remarkable developments of the last ten years—the number of ships of extremely large dimensions is relatively few. These great ships naturally attract most attention; they are admittedly essential to the performance of special services; but the carrying trade of the world is mainly done by vessels of moderate dimensions. The British mercantile marine in 1910 owned 11,495 steel ships of 100 tons (gross) and upward. Of these only 328 ships individually exceeded 7,000 tons (gross), 107 exceeded 10,000 tons, and 20 exceeded 15,000 tons. At the same date there were about 5,000 steel ships on the British register of from 2,000 to 6,999 tons gross individual tonnage; and over 6,000 ships of from 100 to 1,999 tons. This enormous preponderance in numbers of ships of moderate dimensions has resulted from the operation of purely commercial considerations, which have similarly influenced all mercantile marines. Whatever may be the future growth in size of the largest ships built for special services, the bulk of the maritime business of the world will always be done by ships of relatively moderate dimensions, and they will continue to be the largest contributors to the revenues of port and harbor authorities. This fact, as will be shown hereafter, may have an important influence upon the upper limit of dimensions of merchant ships.

III. Naval architects will agree that, provided the money is forthcoming for building still larger ships, their construction will be possible; and that considerably increased dimensions will present no serious difficulty even if the materials for shipbuilding already available were not improved

upon. Before iron was substituted for wood as the principal material for shipbuilding there was a period—within the recollection of the writer and many of his professional brethren who are still actively at work—when an upper limit of size and engine power seemed to have been reached in wood-hulled ships. Since that date metallurgists have made great advances and progress is still being made; and on this side there is no bar to immediate and considerable increase in the dimensions of ships. The margin of possibility indeed appears to go far beyond any probable demand.

IV. Existing physical conditions in the seaports, harbors and docks of the world, necessarily impose limits on the draught of water of ships. Much has been done, at great cost, to improve accommodation and to provide increased depths of water; but it is well recognized that the increase in dimensions of ships above described has been chiefly in lengths, breadths and moulded depths; the increase in draughts of water when fully laden has been relatively small. This is made clear by the figures in Table I. Since 1899 the lengths and depths of Trans-Atlantic steamships have been increased about 30 per cent., breadths have been increased nearly 40 per cent., but deep load-draughts by only 10 per cent. This disproportionate increase in draught of water has imposed difficulties and disadvantages on the work of ship-design which need not be dwelt upon in this gathering. Shipowners find themselves debarred from loading many existing vessels to the full draughts to which they might be safely laden, were there sufficient depths of water at terminal ports and were cargoes available. The earning powers of ships are thus lessened, and in these circumstances it is natural that a demand should have arisen and should still continue, for greater depths of water and better accommodation for ships of the largest size.

While shipowners and shipbuilders urge upon authorities and proprietors of harbors and docks the necessity for prompt and liberal action, the latter may well be pardoned if they do not immediately respond to the demand, but require evidence that the large expenditure which would be needed to carry out these great engineering works will be followed by a corresponding and adequate increase of revenue. The difference in point of view is natural and inevitable. It is idle for those who are interested in ship development to ignore or treat as unreasonable this attitude of dock and harbor authorities who are responsible for a return to investors on the enormous capital sums administered by them. Of course there are some great works which may be and are properly treated as national rather than private or local enterprises. The Ambrose Channel at New York—the navigation of the St. Lawrence and the Kiel Canal furnish examples; but such enterprises are exceptional in character and are avowedly undertaken for the benefit of the

community as a whole, or for strategical reasons which lie outside the present discussion.

V. Up to the present time the response made to the appeal from ship-owners for increased accommodation for larger ships by authorities of the great seaports of the world has been neither niggardly nor unsatisfactory. At the present moment extensive and costly works are in progress which will provide accommodation for the largest ships now building, and leave some margin for further developments. The Ambrose Channel to New York, and the new docks provided at that port for the great Trans-Atlantic liners furnish illustrations of the foregoing statement. At Liverpool and Southampton corresponding works are in course of performance, while still larger schemes are contemplated. It is not necessary to amplify this list, because it is a matter of common knowledge that all over the maritime world the same policy is being followed. Immense sums are being expended on improvements and extensions of docks and harbors as well as on the approaches thereto, both by governments and by proprietary bodies. One of the latest and largest schemes of this nature is that for the River Thames. From reports issued by the new Port of London Authority it appears that the estimated outlay for making the dock and channel accommodation of the Port of London suitable for the existing trade, and for providing a proper margin to meet future developments, will be about 14½ millions sterling (over 72 million dollars).

VI. The marvelous growth of the world's commerce in modern times has enabled these great engineering works to be undertaken hitherto under conditions which have, in most cases, either yielded fair returns to investors in dock and harbor securities, or which have been considered by governments beneficial to the whole nation and worthy of adoption irrespective of the return upon capital expenditure. In many cases this question of dock accommodation has been treated by great corporations—such as railway companies—as parts of their schemes of operations rather than as independent undertakings. Modest returns have been accepted on large sums expended upon docks, because the existence of that accommodation has led to such an increase of earnings on the system considered as a whole, as justified the expenditure on docks. The growth of traffic in most of the great seaports has also enabled earlier docks to be fully utilized by vessels of smaller dimensions than those for which the latest docks have been constructed. But while this has hitherto happened it seems not improbable that a point may be reached beyond which dock and harbor authorities will not care to go in expenditure in order to meet further increase in dimensions and draughts in a relatively small number of the largest ships; and it is well

understood that this consideration particularly applies to increase in draught of water, since the cost of dredging grows rapidly with increase of depth.

It is not my purpose to attempt any prediction of what the limit of depth of water will be in future. For the moment 40 feet of water at low tide seems to be the maximum contemplated; and most ports are content with less, especially when there is a good rise of tide. Keen rivalry between great seaports has hitherto greatly influenced both policy and performance on the part of authorities, and has given shipowners and shipbuilders practically what they have demanded. In the end, however, commercial considerations must prevail, and dividends must be earned by docks and harbors as well as by ships. In dealing with this matter therefore, the conflicting claims and interests of all who are concerned not only with shipping, but with docks, harbors, etc., must have due consideration. The advantages to be obtained by the whole community, and not the profit of a particular section, ought and will determine what is done eventually.

VII. The following brief summary of facts relating to the dimensions of locks and dock entrances recently constructed or now in process of construction may be of interest as indicating the outcome of inquiries set afoot by responsible authorities in regard to the provision of suitable accommodation for the largest ships likely to be built. On the Panama Canal the locks are 1,000 feet long, 110 feet wide, with 40 feet of water over the sills. On the reconstructed Kiel Canal the locks are to be 1,080 feet long, 147 feet wide, with 36 feet of water over the sills, but provision has been made in the structures for increasing this to 46 feet if required hereafter. The new Gladstone Dock at Liverpool is to be capable of receiving the Cunard Steamship Aquitania when she is completed, and still larger vessels; it is really part of a great scheme of dock extension. This dry-dock will be 1,020 feet long, 120 feet broad, with 44 feet of water on the sills at high water, ordinary spring tides. On the Clyde a dock of nearly the same dimensions as the Gladstone Dock, is now under construction with 36 feet of water on the sills at high water; but the rise and fall of tide is less than at Liverpool. The Port of London Authority contemplates the construction of a dock 1,000 feet long, 120 feet wide, with 40 feet of water over the sills. At the new naval base which the British Admiralty are constructing at Rosyth (Firth of Forth) the plans originally provided for a lock 850 feet long, 110 feet wide, with 36 feet of water at low tide, and for a dry-dock of similar dimensions except that it was to be 750 feet long. It is understood that some increase in length and breadth is probable.

Approach channels have been deepened considerably. A depth of 40 feet at low water is to be secured throughout the Ambrose Channel; at

Southampton access is to be secured at all times for ships drawing 34 to 35 feet. At Liverpool the minimum depth of water at low tide in the "cut" through the bar of the Mersey is maintained at 30 feet. On the St. Lawrence works in hand are intended to give a minimum depth of 35 feet from Montreal to the sea—a marvelous change from the minimum of 10 to 12 feet formerly existing on that river during the greater part of the navigation season. On all sides there is and has been recognition of the need for ample depth of water.

VIII. When the foregoing particulars for locks, docks and approach channels are considered in the light of dimensions of ships given in Tables I and II it will be seen that the margins provided in most of the recent engineering works are not very great in regard to length and breadth, although they are expected to prove sufficient for many years to come, because of the commercial considerations above mentioned. To the lengths of ships tabulated must be added about 30 to 35 feet in order to obtain the lengths "over all;" and in regard to breadths it is obvious that good working clearances in breadth are desirable for ease and safety of handling these enormous vessels when passing through dock entrances. This is the more necessary because of the modern tendency to increased height and bulk of superstructures in which much of the passenger accommodation is situated. The effect of wind on the broadside in such cases is considerable and on that account as well as the great effect which tidal currents may have on ships of enormous length relatively wide entrances are needed in order to facilitate docking. As to draught of water, the figures given for merchant ships must be supplemented by about 2 feet to ensure sufficient depth of water under the keels for safe passage over the ground at low speeds. For warships the deep load-draughts in vessels of recent construction are in many instances from 4 to 5 feet greater than the so-called "normal" draughts given in Table II; the displacement tonnages when fully laden require to be correspondingly increased; and when vessels have been damaged by accident or in action, so that their draught has been increased and their trim affected, serious difficulties must be experienced in docking them unless there is a good margin of depth over the sills as compared with the "normal" draughts shown in Table II.

IX. It is a fact worth noting that ships of the maximum dimensions now built or building are not easily accommodated or moved in the largest docks and harbors. The vessels are wonderfully handy, as all who have seen the Lusitania and Mauretania approach or leave the docks at New York, or the landing stage at Liverpool, will agree; but they necessarily require large spaces for their maneuvers because they are so long and heavy, and in

the busy waters of their terminal ports caution is required. It has been stated recently that the provision of suitable docks at New York for the latest Trans-Atlantic liners will involve an encroachment on the fair-way of the Hudson River which may prove disadvantageous to the general traffic of the port. Whether or not this statement is well founded the general truth of the foregoing remark will be admitted. Ships of 900 to 1,000 feet in length, weighing 40,000 to 50,000 tons when deep-laden are not easily dealt with, especially when moving on restricted spaces and in tide-ways, wherein other vessels are under way, and they themselves must necessarily move at low speeds. In many ports also the great draughts of water of the ships impose considerable restrictions on the water-area which they can utilize with safety to themselves. Even in the terminal ports of the Trans-Atlantic steamers difficulties are necessarily experienced, and although they have been overcome so far, they must be accentuated by any further increase of size.

X. For cargo steamers and warships no such fixed conditions or terminal ports exist. The former class are built to seek cargoes everywhere and to deliver them wherever desired. Consequently experience has led to the adoption of relatively moderate dimensions and draught of water, in order that their possible field of operations may be extended widely.

Warships are designed to operate from special bases, but they must find great advantage from being able to enter and utilize other harbors or sheltered waters where the depth of water is moderate. It is desirable also that they should be capable of proceeding to any place where an enemy can be found, and thus enlarge to the utmost their field of operations. Moderate draught of water is therefore an important feature of warship design; and the tendency in recent years to a considerable increase in the deep load-draughts of warships is, from this point of view, objectionable. As above stated the "sinkage" of modern warships (from normal to deep load-draught) is frequently 4 to 5 feet; and although this fact may be ignored in statistical returns it must seriously affect the practical working range of action of the vessels in war time. In respect of draught of water, the United States Navy formerly favored shallowness—indeed insisted upon it—although naval architects did not fail to point out the penalizing influence of that restriction. It will be interesting to be told why this remarkable change of attitude has been made. It is notorious that some of the most recent capital ships added to war fleets cannot when fully laden find shelter in harbors which have been built primarily and at great cost to serve as naval bases, and they cannot be placed in many existing dry-docks, in case of injury in action, because of their considerable load-draughts. It will not be disputed that one essential factor in framing a shipbuilding programme for any war fleet should be the

consideration of the harbor and docking accommodation which will be available, in case of war, for the reception and repair of the largest vessels. For warships as well as for merchant ships expenditure on ships and armaments must be considered concurrently with that on harbors and docks, and in every well-devised programme the two things must be dealt with concurrently. This is a truism, no doubt; but past events prove that it may none the less be neglected in the excitement of a race to produce the "biggest warships" each carrying the greatest number of the heaviest guns.

XI. Enlarged dimensions, of course, enable certain advantages to be obtained, outside the fundamental gains of economy in sea-transport or increased speed. Amongst these advantages are:

(*a*) Maintenance of speed at sea in rough weather, and increased uniformity of service between terminal ports.

(*b*) Greater steadiness and good behavior in rough water and increased comfort for passengers, if naval architects are left free to utilize fully the greater size of ships. Not infrequently they do not enjoy such freedom, because the conditions laid down impose limitations on their choice of dimensions and proportions.

(*c*) Better and more spacious accommodation for larger numbers of passengers.

(*d*) The attraction which many passengers have toward the "biggest ships afloat."

A few remarks may be added respecting the first and second of these supplementary gains due to larger size in passenger steamships.

Maintenance of speed in rough seas and storms is obviously affected by the relative dimensions of ships and waves. Storm waves in the Atlantic Ocean and elsewhere attain certain maximum dimensions. The observations of Dr. Scoresby, Lieutenant Paris, and others have enabled us to accumulate a great body of information respecting the sizes and speeds of ocean waves, and more than thirty years ago I brought these facts together in the "Manual of Naval Architecture." Certain additions to our knowledge of wave-phenomena have been made since that date, but the main facts remain substantially as I stated them in 1877 for the information and guidance of naval architects. Ocean waves have not grown in size because larger ships have been built; and obviously there must be an upper limit of size, beyond which, so far as maintenance of speed is concerned, further increase in the dimensions of ships will have little or no effect upon regularity of performance of service between terminal ports. I have previously recorded my opinion that this upper limit of size has been reached for the Trans-Atlantic service in the Mauretania and her sister ship, and I will now briefly state certain facts on which that opinion is based.

The Mauretania has averaged for a whole year, on 30 consecutive passages (15 voyages) westward and eastward, in all weathers and under varying and uncontrollable conditions of service, a mean speed of 25.5 knots. The highest mean speed going west was 26.06 knots; coming east it was 25.89 knots; the lowest mean speed was 24.92 knots in both directions. This regularity of performance has been repeated during service in two following years, the average mean speed being 25.25 knots and 25.1 knots respectively. In the series of passages made between February and August this year; the total number of revolutions of the screws during each passage varied only two per cent. above or below the number of revolutions per passage deduced from an average for all the passages. These figures may be left to speak for themselves. A closer approach to regularity of performance on the Trans-Atlantic service can hardly be realized whatever may be the sizes of the ships employed.

Experience proves also that in the Cunarders the limit of speed at which they can be safely driven in heavy seas is not fixed by their size, engine power, or general structural strength, but by considerations of the serious damage which might be done to fittings and navigational appliances as well as to the officers and crew employed in navigating the ships, and of the safety of passengers if the ships were driven at high speed against heavy seas. No prudent commanding officer is likely to incur unnecessary risks in these directions; and so there comes a time when the vessels are not driven at full speed against heavy seas but are slowed down until the weather moderates. This will always remain true whatever the sizes of ships may be.

In regard to steadiness in a seaway, long experience has shown that ships of less size may be more free from heavy rolling in a seaway than much larger ships, if the latter are endowed with greater stiffness and consequently move more quickly when rolling. Speaking on the basis of numerous personal observations made on ocean voyages, I can testify that this is the fact both for merchant ships and for warships. In recent years increase in the proportion of breadth to draught of water has tended to shorten periods of oscillation. No doubt in modern passenger steamers the lofty superstructures tend to raise the center of gravity and so to diminish stiffness and lengthen periods of oscillation. The increased breadth of ships has also tended to lessen the "effective wave-slope," and so to diminish rolling. Apart from detailed calculation no exact knowledge can be reached respecting the probable behavior and period of oscillation for a new ship; but that fact in no way contradicts the general statement made above, that large dimensions are not necessary to secure moderate rolling and easy motion. In modern warships of the largest types, as I pointed out in the paper read

last year to this Society, the periods of rolling oscillation are actually less than the corresponding periods for smaller ships which preceded them; and it is certain that, as a result, the larger ships must prove less steady gun-platforms than their predecessors under the influence of ocean storm waves, such as are frequently encountered.

XII. In view of the foregoing statements it becomes apparent that larger dimensions are not essential to good behavior at sea, and that increase in length and weight beyond the Mauretania is not necessary in order to secure maintenance of speed on long ocean passages. It would appear therefore that the main determining factor in regard to maximum dimensions for future mercantile vessels must be found on the commercial side and not on the technical. If ships cannot be made to pay dividends on the capital sums invested in them—after meeting working expenses and cost of upkeep, and making due allowance for insurance and depreciation—they are not likely to be built.

The first cost of Trans-Atlantic passenger steamers has been increased enormously during the last forty years. In 1874 a 15-knot steamer cost £200,000; in 1889 a 20-knot steamer cost £375,000; in 1893 a 22-knot steamer cost about £550,000; in 1899 the Oceanic, of 20.75 knots, with relatively good cargo-capacity, cost £700,000; four years later a 23-knot steamer of about the same dimensions as the Oceanic cost £800,000. For later ships authoritative figures have not been published, but certain statements indicate approximately the sums which have been spent upon them. The British Government granted to the Cunard Company a loan of £2,600,000 toward the construction of the Lusitania and Mauretania, and it is understood that the actual cost of the two vessels exceeded that amount. The outlay on the Olympic has been put at about one and one-half million pounds sterling by men who had exact knowledge of what she has cost. The Hamburg-American and Cunard steamships now building would, on this basis, represent an expenditure of about one and three-quarters million pounds sterling per ship. There can be no doubt that experienced men who guide the policy of these three steamship companies have reached the conclusion that even such huge expenditure as these figures indicate will, on the whole, prove advantageous to the owners and lead to increased revenue.

It is not my purpose to attempt even the roughest estimate of earnings or working expenses for the new vessels. On the other hand it may be well to call attention to certain facts and opinions which are already public property and which bear on the subject. In 1902 a committee appointed by the British Government to consider and report on the employment of mercantile cruisers and the subsidies proper to be paid for the services of

such ships, expressed the opinion that commercial companies would require to be paid annual subsidies for swift steamships in order to make good "the loss which would be sustained in peace time for running such vessels." For ships having a sea-speed of 25 knots the committee considered that the annual subsidy ought to be 15 per cent. of the first cost; for 23-knot vessels, 8.6 per cent.; for 20-knot vessels, 2.6 per cent. The essential point in this recommendation was that extremely fast vessels could not be worked without loss, and that if they were to be made available for use as auxiliary cruisers in war, annual subsidies should be paid. National sentiment was strongly in favor of recovering ownership of the swiftest ocean steamships for Great Britain; Parliament approved that action; an agreement was made with the Cunard Company to build the Lusitania and Mauretania; an annual subsidy of £150,000 was arranged; and the loan above-mentioned was granted at 2¾ per cent., to be repaid in twenty years. Only the owners of these two vessels can know whether or not they have earned dividends and it is their concern alone. It is noteworthy, however, that no attempt has yet been made to surpass these vessels in speed, and that the five ships of greater size for which particulars are given in Table I are intended to be slower than their predecessors. They may, in fact, be regarded as the latest developments of the "intermediate" type of Trans-Atlantic steamships, rather than as additions to the series of "express" passenger steamers in which very little cargo is carried, of which the Cunarders are the latest examples.

The essential characteristics of the "intermediate" type of steamships are moderate speed in proportion to length and displacement, and the association of large passenger accommodation with a considerable cargo capacity. Moderate speed, of course, permits of relatively moderate engine-power, lessens the coal-bill and engine room expenses, makes less demands for space for engines, boilers and fuel, and leaves free for other uses a larger proportion of the internal capacity than in express steamers. All these differences obviously tend to increase net earnings in vessels of the intermediate type relatively to express steamers of equal size, but much higher speed; provided that passengers and cargo can be obtained. On the other hand if cargoes are obtained which utilize the full dead-weight capacity of a very large steamer of the intermediate type, it may happen that the period of detention in port may be considerably in excess of that required for the passenger service and for recoaling. As a consequence there may be so considerable an increase in the time spent in port—during which the capital is unproductive—as will seriously diminish the net earnings. Every one agrees that for large and costly ships a quick "turn round" is of vital importance to commercial success and the shipment and discharge of large cargoes must interfere with that procedure.

It is not my purpose to attempt any detailed discussion of this branch of the subject, nor have I the experience which would enable me to do so. Speaking to naval architects, however, it may be permitted to make a brief statement which will illustrate the points last raised, and show the essential differences between the Mauretania and Olympic, the first costs of which probably approximate. Let it be assumed that the two ships start at the same deep load-draught—34 feet. Allowing for differences in speed and engine-power the coal burned for propulsion on a Trans-Atlantic passage by the Olympic at 21 knots would be about 70 per cent. of that required for propulsion by the Mauretania at 25 knots. For other purposes the daily coal consumption of the Olympic would rather exceed that of the Mauretania because of her larger size and greater number of passengers. The duration of the passage would be about 20 per cent. longer for the Olympic and on this basis the dead-weight cargo capacity of the Olympic at the load draught assumed for both ships would probably exceed that of the Mauretania (roughly) by 10,000 tons. This is obviously a potential source of larger earnings, provided cargoes can be secured and dealt with in port without objectionably long detention. It may be doubted whether this full cargo capacity would be frequently utilized, even coming eastward, and going westward there would be no prospect of its utilization under the conditions of actual Trans-Atlantic service. If not so utilized the vessel could of course be worked at lighter draught, or could carry coal from England for the voyage out and home, or be otherwise dealt with. On the other hand the under-water form would always remain that which was selected as appropriate to the carriage of a large dead-weight; and if the provision made for cargo had been less it would have been possible to produce a vessel of smaller displacement and less cost having the same speed, with reduced working expenses and equal passenger accommodation. These remarks are made in no spirit of criticism. Those who were responsible for the construction of the Olympic are undoubtedly masters of all details of shipping and ship management, while I am only an outsider in mercantile affairs and necessarily regard the problem from the point of view of a naval architect. Even that point of view should not be ignored, however, and it will have an influence on the future development of mercantile steamships.

XIII. For warships other considerations than those of first cost and cost of maintenance must determine the maximum dimensions which should be adopted. Their case is, therefore, distinct from that of merchant ships and must be considered on its merits. Advocates of further increase in size and cost of warships take a different view and argue that because a few mercantile steamships have reached dimensions far in excess of those attained

by warships, therefore it is reasonable to follow a similar course in warship construction. This argument has already been dealt with indirectly in Section X of this paper. The comparatively few merchant steamers of very large dimensions now in existence have been built for special service between known terminal ports, whereat proper accommodation for them has been provided. Their employment consequently differs radically in character from that of warships which are intended to seek out and find an enemy wherever he may be. In order to secure success, therefore, each navy needs a considerable number of ships, and the draught of water of individual vessels ought to be moderate in order that their field of possible operation should be large.

Warships are also exposed to special risks, to which there is nothing corresponding in the services for which great mercantile steamers are constructed; and as a consequence it is essential to provide for considerable numbers as well as for individual power in the constitution of each fleet. It is admittedly a correct definition of the problems involved in the arrangement of an "establishment" for any navy, to say that it must rest on a definite plan of campaign, the fulfilment of which requires the construction of a certain number of ships of various types suitable for various services, and ranging from capital ships—forming units in squadrons and fleets—down to the smaller classes of armed vessels and the fleet auxiliaries. For each fleet of capital ships it is necessary to arrive at a decision as to the best distribution of the total sums to be expended on construction and subsequent maintenance; and in reaching such a decision regard must be had to the special risks incidental to modern naval war, as well as to the necessities of naval operations which must demand the capability of either concentrating or distributing the force as the varying conditions of a campaign may require. Problems such as these naturally, indeed necessarily, give rise to different solutions, and there is room for various opinions as to the best possible arrangements in proportion to total expenditure. My personal opinions on the subject were expressed in the Paper on "Armaments of Battleships" which appears in the Transactions of this Society for last year. It may assist the present discussion if they are briefly summarized.

(*a*) Multiplication of the heavy-gun positions in capital ships, and of the number of such guns carried by individual ships, has necessarily involved increase of lengths and displacements.

(*b*) Concurrently with this alteration of armament there has been an increase in speed and fuel supply: this has involved further increase of size.

(*c*) Modern capital ships—with heavy-gun armaments and great weights of armor placed high above water—must be endowed with considerable initial stability in order to possess a reasonable range of stability under

ordinary peace conditions. Hence they have been made very broad in relation to their draughts of water—even after allowance is made for the increase in draught (deep laden)—as compared with their predecessors.

(*d*) Their moderate range of stability (when intact) gives to these ships a less margin of safety when injured in action by gun-fire; and, in many instances, the distribution of the armor is of a character that adds to this risk, because it leaves without protection large areas of the sides which are reckoned as water-excluding in calculations of stability, although they can be rapidly riddled and destroyed by shell-fire with high explosives. In later designs the areas which are armor-protected have been considerably increased; but the addition to the weight of armor placed high above the water-line has necessarily been accompanied by a rise in the position of the center of gravity of the ships. The breadths have been still further increased in porportion to the draughts, and even then the range of stability in the intact condition is very moderate.

(*e*) Modern warships, notwithstanding their greater size, are not, and cannot be as steady gun-platforms as their predecessors; because their great initial stability causes them to have relatively short periods of oscillation. As a consequence they are more likely to be set rolling by ordinary conditions at sea. Experience has shown them to be less steady in a seaway than ships of earlier date and smaller size. Some of these ships are so large in relation to the available dry-docks that their bilge keels are either very shallow or non-existent at the midship portions of the length; and as a consequence the check upon rolling is greatly reduced.

(*f*) The development of under-water attacks proceeds rapidly. Torpedoes are now larger, have greater charges, are much faster and can be used at much longer ranges. Submarine mines have been used with great effect in actual warfare, and will be used in future with greater effect. Submarines have been developed, and are now being made of dimensions, speed, and radius of action which probably enable them to act as auxiliaries to fleets over considerable areas of operation. Advocates of very large dimensions in warships admit that one successful under-water attack will probably put the largest warship out of action. It cannot be questioned that the increase in length and speed of recent ships will necessitate an increase in the intervals between successive ships in the line of battle, and the danger of successful under-water attack will be increased because both individual ships and the line of battle formed by a certain number of ships must be made longer.

(*g*) In view of the foregoing considerations it appears to be desirable to put a limit upon the size and cost of individual warships, and the concentration of so many guns in a single ship; because a single successful blow may bring about a serious proportionate loss to a fleet by one ship being

put out of action. Moreover, the withdrawal of a single ship from a fleet, for temporary employment on detached service, would involve a serious loss of power, which with more numerous vessels would be avoided.

(*h*) Special dangers must be incurred by the multiplication of heavy guns and of magazines placed below them. Some of these magazines are necessarily in the neighborhood of boiler-spaces or bunkers, where high temperatures are unavoidable. No doubt the dangers are lessened by fitting appliances for keeping magazines cool and by other devices; but although lessened they are not absolutely overcome and the risk of explosion—as sad experience proves—remains. The loss of the Liberté, which is universally deplored, following upon a previous accident to the Jena, demonstrate the possibility of possible and sudden destruction in this fashion of the largest ships and furnishes a fresh argument against "putting too many eggs in one basket."

My personal conviction, based upon long-continued study of the problem, is that the wiser course in warship building would be found in a return to more moderate dimensions and a reduced unit-cost for capital ships. Experience has established the fact that, without having resort to the extreme dimensions which have recently found favor, it is possible to produce capital ships which shall be powerfully armed, well protected, steady gun-platforms, capable of fighting their guns in all weathers when actions could take place, and able to maintain their speed in rough water. The value of high speed in capital ships has been much discussed, but it really opens up a separate field into which it would be undesirable to enter now. Suffice it to say that with equal speed a reduction in the number of heavy guns carried in a single ship such as I advocated last year would enable considerable reductions to be made in size and cost; and that, for a given total expenditure on the first cost of a fleet or squadron, a more formidable and flexible force could, in my judgment, be obtained, with greatly reduced risks from either gun fire, under-water attacks or magazine explosions. It would probably be true, that the more numerous fleet would cost more for manning and maintenance, but the price which would have to be paid in this direction would be well earned by advantages in other respects; and above all by a greater prospect of success in the day of battle.

In conclusion let me express the hope that the discussion which this paper is intended to provoke may have as its main result the discovery and record of points on which there is substantial agreement; and that it will put on record a clear as well as a reasoned statement of points on which differences of opinion exist as well as the reasons for such differences. No doubt, in the end, we shall have to "agree to differ" respecting some matters; but it will be of advantage to have minimized these differences and to know how far we agree.

TABLE I.—TRANS-ATLANTIC STEAMSHIPS.

Line.	Name.	Date.	Length, feet.	Breadth, ft., in.	Depth, ft., in.	Gross tonnage.	Load draught, ft., in.	Load displacement, tons.	Horse-power.	Sea-speed, knots.
Cunard	Persia	1856	360	45 0	31 5	3,300	23 0	6,000	4,000	13
White Star	Germanic	1874	455	45 0	36 0	5,000	23 0	8,500	5,500	16
Cunard	Oregon	1883	500	54 0	40 6	6,900	23 0	10,500	13,000	18
White Star	Teutonic	1889	565	57 6	42 0	9,700	23 0	13,000	20,000	20
Cunard	Campania	1893	600	65 0	41 6	12,500	27 6	20,000	30,000	22
White Star	Oceanic	1899	685	68 5	49 0	17,274	30 6	26,400	26,000	20.75
North German Lloyd	Kaiser Wilhelm II.	1903	678	72 0	52 6	19,360	29 0	26,000	38,000	23.5
Cunard	Mauretania	1907	760	88 0	60 5	31,938	34 0	39,000	75,000	25.5
White Star	Cedric	1903	681	75 3	44 1	21,000	32 0	32,000	13,000	16.5
White Star	Adriatic	1906	709	75 6	52 6	24,540	34 0	36,000	16,000	17
White Star	Olympic	1911	850	92 0	64 3	45,000	34 0	50,000	46,000	21
Hamburg-American	Imperator	Building.	880	96 0	64 0	about	34 0	to	not	22
Cunard	Aquitania	Building.	885	95 6	.....	50,000	34 0	55,000	stated	23

Table II.—Armored Warships.

Navy.	Name.	Date of order.	Length, ft.	Breadth, ft.	Load-draught, ft., in.	Load-displacement, tons.	Horse-power.	Trial-speed, knots.
British	Warrior	1859	380	58	26 0	9,000	5,500	14.4
British	Bulwark	1899	400	75	26 9	15,000	15,000	18
United States	Maine	1898	388	72¼	25 6	13,500	16,000	18
German	Wittelsbach	1899	394	68¼	25 0	11,900	15,000	18
French	Suffren	1899	410	70	27 6	12,700	16,500	18
British	Lion	1910	660	88½	28 0	26,400	70,000	28
United States	Wyoming	1909	554	93¼	28 6	26,000	28,000	20.5
German	Moltke	1908	610	96¾	27 0	23,000	50,000	25.5
French	Jean Bart	1910	541	88½	29 6	23,100	29,000	20
Argentine	Rivadavia	1910	585	96	27 6	27,500	39,000	22.5

DISCUSSION.

THE PRESIDENT:—I am quite sure you have all enjoyed this paper, and I take great pleasure now in calling on Past President Bowles to have his say.

PAST PRESIDENT BOWLES—Mr. President and Gentlemen, I will take my little note book and descend into the arena. (Laughter.) As one of his first American pupils, and possibly his oldest pupil here present, it is a great satisfaction to me to express the cordial appreciation of this Society at the presence of the distinguished author of this paper.

It is a great pleasure to those of us who are present, and an honor to the Society, that such a very old question as the maximum dimensions of ships, and at the same time such an ever new and present problem, should be presented to us in such a masterly way. The paper to me discloses throughout, perhaps unconsciously, the attitude of the naval architect in the problem that is always presented to us, of accomplishing the results of a design on the least dimensions, and therefore it might not be disrespectful to change the title of this paper to "The Minimum Dimensions of the Maximum Ship."

The author has stated in the beginning the pertinent questions on the subject and appears to have satisfactorily answered them himself. In answer to his first question, "Is it probable that the dimensions of ships will continue to grow at the rapid rate which has prevailed in recent years," he is inclined to answer No, but he admits that the dimensions of the average merchant vessel will probably contine to increase, and, indeed, the reasons which he gives are capable of reinforcement, because the matter depends largely upon the development of terminals for commerce. There is now throughout the world a remarkable activity in the development of steamship terminals, not only in the United States, but throughout the world, which will have undoubtedly a profound influence in this respect, and, as the author states, a beneficial one.

In answer to his second question, "Will an upper limit to the sizes of ships be reached?" he admits that this question does not depend upon the naval architect, but upon the condition of terminals and financial considerations.

In approaching the discussion of his questions and the considerations which he advances which are likely to determine such limits for either merchant or war vessels, he discloses some matters of opinion to which I venture to call attention.

He asks for some explanation of why the United States has abandoned as a feature of its battleship design a moderate draught of water. Possibly, it is not becoming in me to attempt to furnish the answer to that question, but having grown up with the new Navy I am inclined to try it. When we started out in 1882 to build a new Navy in the United States the people of this country regarded

a naval force as one solely for defense, and it was with the greatest reluctance that Congress approached the idea of building a battleship. Mr. Nixon was limited in the scope of his design by the necessity of calling it and making it a coast defense ship. That original condition continued until the people of the United States realized that we had grown to a different situation amongst the nations of the world, so that when the head of one of the foreign navies asked me for the justification of the size of our battleships, saying that they were able to lay out the plan of campaign and say where battles would be fought, and so limiting the size of their ships, I replied to him that the United States was unable to locate the field of a possible battle and that it felt that its battleships must be so designed that they were capable of going anywhere and fighting when they got there.

The author first discloses his well known position in favor of moderate dimensions by recording his opinion that the upper limit of size has been reached for the Trans-Atlantic service in the Mauretania——

Sir William Henry White:—Excuse me, I did not say so. I said that the upper limit of size reached in the Mauretania gave you all that was wanted to insure regularity of passage. That is all.

Past President Bowles:—I quote again from Sir William's paper: "I have previously recorded my opinion that this upper limit of size has been reached for the Trans-Atlantic service in the Mauretania." I am reading on page 10, near the bottom of the page.

Sir William White:—So far as maintenance of speed is concerned. Look a little further, please.

Past President Bowles:—Now, no doubt the designers and builders and owners of the Mauretania and Lusitania, in the production of these triumphant vessels representing the acme of luxury in ocean travel, having been presented with the funds, thought not only to take the next step in Trans-Atlantic naval architecture, but to skip a few of the following steps. Whether they have accomplished that or not remains to be seen. They have been answered by the construction of even greater vessels, of more moderate speed and of greater passenger accommodations.

The author of the paper under consideration has seen fit to question the earning capacity of this cargo capacity of the newer vessels. Now, I would enter on the discussion of that matter with much greater diffidence than the author refers to himself. But I approach very seriously the statement in his paper where he discusses this feature of the Olympic, intimating that a vessel of smaller dimensions, without this cargo capacity, could have been produced with equal passenger accommodations. That leads me to remind you that the most profitable part of the traffic on a Trans-Atlantic liner is the transportation of steerage passengers.

They constitute a very attractive cargo, because they get on board on their own feet and they discharge themselves without the use of any elaborate machinery. They even venture fearlessly into the toils of the custom house and the emigration service and emerge therefrom in incredibly less time than any inanimate object can. (Laughter.)

If we in the interests of our country shall do, as we ought to do, all that we can to regulate and reduce and distribute the immigration traffic to this country, it would have a more marked effect upon the maximum dimensions of vessels than any consideration advanced before us to-day.

Now, coming to the subject of the maximum dimensions of battleships, I quote from page 17, as follows: "My personal conviction, based upon long-continued study of the problem, is that the wiser course in warship building would be found in a return to more moderate dimensions and a reduced unit-cost per capital ship." And again on page 17: "With equal speed a reduction in the number of heavy guns carried in a single ship such as I advocated last year would enable considerable reductions to be made in size and cost; and that, for a given total expenditure on the first cost of the fleet or squadron, a more formidable and flexible force could, in my judgment, be obtained, with greatly reduced risks from either gun fire, under-water attacks or magazine explosions."

That is a very interesting opinion to me, and it reminds me of a most interesting incident which occurred at a time when I occupied a position of some authority. At that time a distinguished school of advocates broke loose, headed by a most distinguished naval historian, advocating this same idea of the advantage of a greater number of vessels. The distinguished historian wrote an elaborate memorandum for the President of the United States setting forth his conclusions as deduced from the experience of Nelson and Howe and the development of the frigate as compared with the efficiency of the line-of-battle ship, and I had the pleasure of discussing that matter and was able to point out, as has been done by others since, that the mobility and handiness of the modern battleship made all points of comparison between the experience of Nelson and Howe absolutely valueless. Suffice it to say that the result of the discussion which occurred at that time convinced President Roosevelt that he wanted the biggest ship, and that decided the design of the Connecticut and Louisiana and a considerable class of vessels following.

I had the pleasure of laying before this Society a very brief paper setting forth the facts and figures of the greater fighting capacity which resulted from the increase in dimensions of these battleships and armored cruisers. It is not necessary to recapitulate these figures, but they were similarly and adequately set forth in the paper by Professor Welsh before the Institution of Naval Architects this spring, in which he showed that an increase in displacement of 34 per cent. and an increase in cost of 50 per cent. in a battleship would result in a doubling of the effective gun power. I do not base my idea of the advantage of increased size in battleships wholly upon any rigid rule as to the amount of the broadside discharge or the calibre or number of the guns.

I wish to introduce into this subject considerations which I have never seen before advanced at all, and that is, that comparing a small battleship with a large battleship the efficiency of each gun on the large battleship is enormously greater from a variety of conditions. In the first place, in a small battleship, everything is more or less close together, all the turrets are necessarily near the machinery, or the magazines are necessarily more or less near the heated parts of the ship. If the dimensions are too small, it is impossible to obtain any effective protection against submarine attacks, and the seaworthiness of the vessel is less. Of course, it is possible to produce similar rolling conditions in smaller ships, but stability nor rolling conditions in a seaway do not constitute seaworthiness. They are a very small fraction of it.

In the larger vessel, in addition to these features which I have described, there is a human element of efficiency which affects every gun compared to the smaller ship. In the first place, in the large ship there are greater safeguards with regard to the supply of power, the supply of ammunition and the supply of every essential element that goes to the gun. In the next place, there is a very much greater crew, a very much greater complement of officers, and there is this inevitable human fact, that the best men go to the best ships.

Now, these considerations which I have only advanced to you in the most brief outline are those which, in my judgment, influence the wisest naval officers and the wisest seagoing officers always to vote for the biggest ship. Admiral Bacon said that the bigger the ship becomes the less vulnerable she is. I say that in the biggest ship the human element of efficiency adds enormously to the power of every gun.

THE PRESIDENT:—Mr. Nixon, may we hear from you in discussion of this paper?

MR. LEWIS NIXON, *Member of Council:*—Mr. Chairman and Gentlemen, I share with Admiral Bowles in the pleasure we have all had in hearing this most excellent paper by so eminent an author. His reputation in the world as a naval architect gives to it a great weight. I may say that in reading it I find arguments for increased dimensions.

Admiral Bowles has gone into some of the technical points, which effect this matter, and my desire is simply to touch upon a few of the reasons which Sir William advances as against the possible increasing dimensions.

I think the limit is not as stated in paragraph III, but the power of utilizing to the fullest every ton of displacement you have. Size I consider a complement only in the development of the steamship to the various uses to which it may be put. Of course, we cannot have all the ships large, and hence a good deal of this argument which covers the use of ships of the ocean would not apply, because we have the smaller ships ready to take part in this particular service.

Sir William dwells a great deal upon the question of harbors and docks. The

history of our Lake traffic is probably the best we can call upon to show what that means in the development of large ships. In the '80's we deepened our harbors and the approaches to 16 feet; in the '90's we increased this to 18 feet, and lately we have increased it to 21 feet. The response has been so remarkable as to be almost a miracle in the development and use of greater tonnage for carrying trade on the Great Lakes. We not only have done that, but last year I was in Buenos Aires, and I find that they, too, appreciate the advantages of deeper harbors, and as fast as they can deepen them they are doing so, and the response is even greater than you would expect, in other words, the commerce of the port is running away from them, and they cannot provide as fast as needed the facilities for the larger ships that are coming there.

As regards some of the shippers not possessing the necessary enterprise to deepen their harbors and docks, I will only say that those cities that show the greater enterprise will reap the greater reward, and in the course of time the other cities of this country and other countries, that see their neighbors getting ahead of them, and taking away the business which ought to go to them, will rise to the occasion and deepen the ports of their cities to suit the greater draught of vessels, if it is required by the interests of commerce.

Sir William refers to the Panama Canal. I quite agree that 40 feet seems to be the low limit for that particular canal, and it is probable that ships will want to use that draught, at least. Ships will come deep laden with coal to serve their uses that far, and then coal on the other side, and be able to use the deeper draught at the point of departure.

As regards our own harbor, I remember a few years ago coming back from England, just as we finished our new Ambrose channel, of which we were so proud. The commander of the ship told me he was going up the new channel. In going up the channel early in the morning we twice had to slow down for a little sailboat not over 16 feet long, which, secure in its right-of-way, came cooly down the channel, when it should have taken its course in another part of the harbor. I think those who know something of the handling of commerce in this harbor must realize that the time is coming shortly when there must be a drastic regulation in favor of the great interests centered here, the merchandise of which is carried in ships of great bulk and size, that will require that no vessel shall move in the harbor of New York, or at least in the channels through which the great steamers pass, unless under power control. We must have such a regulation if we are to rise to the responsibilities of the occasion.

Of course, we must not assume that all vessels should be larger because some must be.

The author says: "It will not be disputed that one essential factor in framing a shipbuilding programme for any war fleet should be the consideration of the harbor and docking accommodation which will be available, in case of war, for the reception and repair of the largest vessels." Admiral Bowles has told you something of the history regarding our first battleships which were to be made 8,500

tons. They were made 10,500 tons, and no one was court martialed for exceeding that particular limit. We were told these ships had to be produced on a draught of 22 feet, and we have built others of deeper draught, and the wisdom which has been forced upon the country by the building of these vessels, has provided the necessary docks for these deeper vessels; and if the wisdom of those who control the naval policy of this country in the future calls for greater depth of battleships, you will find the people of this country will rise to the necessities of the case and give the necessary facilities for docking and repairing. Notwithstanding the fact that some of the docks of to-day cannot take the larger ships, many are convinced that nothing should stand in the way of getting the best; if the best is hindered by the necessary facilities as to docks and arrangements for repair, absent at the present time, in my opinion they will be fully provided as the necessity occurs.

As regards the Mauretania and Lusitania, last November I crossed in the Mauretania, and one day we slowed down to 19 knots. I was in the chart house with the captain and inquired the reason for slowing down, and he pointed out a dent made in the thick plate in front of the chart house by a wave on the previous voyage which had struck nearly 70 feet above the water line.

Now, the author of the paper says that it is a question of regularity of passage which has been the first consideration in the production of these ships. That is true. They do make fairly regular passages, but so do smaller boats, they make regular passage, but regularity of passage is not all that we must consider. Of course, battleships are made to fight, and storms do not blow for the maximum part of the time. We may have moderate weather and perfectly calm weather, but steamships must go on their course regardless of waves or conditions, and make speed. With a great ship of the size of the Mauretania, under what was a fairly moderate gale, we had to slow down, and that is a very good index of what the naval architect must come to; in other words, if you will take the small ship of fifty years ago, or even twenty years ago, and then take the newer ships, you will not see much difference in the general appearance of these ships. If to drive ships through the water at 25 knots an hour leads to the possibility of carrying away some parts of the equipment, due to the character of its construction, or due to the shape of the ship, then let us find some means by which we shall apply to the upperworks of the ship such elements of construction as will make it possible to drive the ship under all conditions of stress and storm, without running the risk of disaster of any kind.

I quite agree that possibly we may have to go to a very much larger size of ship in order to do this, and it is possible that to go through what would be considered the average storm conditions of the North Atlantic sea during the month of November, and not have the speed fall below 25 knots, will require ships of very much increased length. This was impressed on me when I made this passage to which I have referred. I know at that time, when I crossed in November, for two days there were only about ten persons in the dining room, so you can understand there was a fairly heavy sea, and yet one which I would not call a gale in any sense of the word.

Stability is not what we must arrive at so much in our ships, as Admiral Bowles has said and Sir William has said. Of course, we can get this quality in smaller ships——

SIR WILLIAM WHITE:—You mean steadiness?

MR. NIXON:—Yes, steadiness. Absolute regularity of arrival and departure possibility is not so strictly necessary. It is a question of dollars and cents to which we must figure the matter in the long run, and in figuring this question of dollars and cents we must take into consideration that if we build a ship to do a certain work, and then the ship is not able to do the work from the fact that we have not deep enough harbors to dock it, that we are failing to realize the object for which the big ships were built.

Sir William makes the statement: "If ships cannot be made to pay dividends on the capital sums invested in them—after meeting working expenses and cost of upkeep, and making due allowance for insurance and depreciation—they are not likely to be built." But what about the converse of that proposition? Suppose they will meet working expenses and cost of upkeep, then does not the inference follow that we must have greater and greater ships if we can make them pay. We know perfectly well that in the history of handling freight upon the ocean, the big ships put the little ships out of business every time, but, of course, if we get these ships so big that we cannot utilize their displacement to the best advantage, that great advantage of size will not hold——

SIR WILLIAM WHITE:—That is my point.

MR. NIXON:—Sir Henry gives some very interesting light upon the building of the Lusitania and Mauretania to the effect that the British Government has granted a loan of 2,600,000 pounds sterling, at $2\frac{3}{4}$ per cent., to be paid in twenty years, and a practical subsidy, which would pay this amount back to the steamship company. I will not go into a discussion of that policy, but here are the two greatest ships of the world brought into competition with the carrying trade on the North Atlantic, held there by the power of the great Government, and may we not hope that our Legislative bodies will take from that a lesson and find a way by which we can put some ships on the ocean and then drive them fast in spite of the gales.

Sir William speaks of detention. It is quite true we might to-day in the harbor of New York be unable to unload boats and reload them and clear them, in the time during which they are in port. Is not that another consideration for the attention of the naval architects? Is it not a question of brains? If we are to build our boats in these large sizes, and have not brains to design methods by which we can unload them, are we not wanting in some capacity in our particular chosen profession? Go up to the Lakes and see what they have done there. I saw 10,000 tons of ore loaded in a few hours. It is a question requiring study,

and if that is one of the limitations, and I am only speaking of the limitations—because it would take too long a time to go into any other questions—the questions brought up by Sir William as to the regularity and size of ships, etc.—I want to say it is a problem for us to study, and if we give it proper study we will certainly be able to meet it.

The question of handling men and handling traffic is largely the same. I recall a few years ago in Europe talking to some distinguished generals, and they were telling me it would take six hours to detrain an army corps. I said—"Gentlemen, I can take you to Chicago and show you where we detrain 40,000 hogs, water and pen them in one hour, and if we can do it with hogs why cannot you do it with men?" So I say that when it comes to the question of the unloading of freight that the genius and the capacity of the mechanical engineer will meet that problem, and if that is one of the barriers to the adoption of greater dimensions, and the utilization of increased cargo capacity, I want to say that I do not believe that barrier is one which should stop our progress. The last cry in handling freight, gentlemen, has not been reached by any means.

Now, as to the size of battleships. I think it is a question in battleships of probably the bigger the ship the bigger fighting power you put in, that is what you are after when you build big ships.

Sir William speaks of the multiplication of heavy-gun positions in ships, and that the number of such guns carried by individual ships has necessarily involved increase of length and displacement. As long as you can place the guns to good advantage, and get away without interference, there will be practically an increase in the number of guns carried, provided it is an advantage to carry them.

He speaks of the increase of weight due to speed. I believe that the genius of the naval engineer and marine engineer will keep pace with the needs for greater power in our ships, and we shall be able to produce the power on less and less weight, and that the increased speed will be gotten at a less and less proportionate net dead weight.

He speaks again of the dry-docks as affecting the battleships, and I can only say that if that affects the possible size of the ship, that we have the genius to take care of that problem in the future as we have done it in the past.

Sir William says,—"My personal conviction, based upon long-continued study of the problem, is that the wiser course in warship building would be found in a return to more moderate dimensions than a reduced unit-cost for capital ships." The moderate dimensions of to-day may be very small for the dimensions of to-morrow, or the maximum dimensions of to-day may be the moderate dimensions of to-morrow. It depends on the demands we make on the naval architect.

As regards guns, Sir William says:—"Special dangers must be incurred by the multiplication of heavy guns and of magazines placed below them." Admiral Bowles covered this point as far as the present type of guns is concerned. While I thoroughly realize the danger of attempting to prophesy, I believe that modern inventive genius is going at such rapid rates that it is a question of only a few years,

which you can count on the fingers of your two hands, when the idea of hurling through space a mass of steel impelled by a gun will be as obsolete as the sling of David. There will be a change in the offensive power of ships, and that will be carried in larger and larger ships. That is a prophesy. I probably will have to be called to account for it, but I believe it is absolutely in the making at the present time.

Of course, you can make a great argument as to the tremendous disadvantage of losing one ship. Possibly when a commander gets into battle, it is wise for him to think of the possibility of the loss of his ships, but the best thing for him to think about is to disregard the possibility of loss of his own ships and think more about accomplishing the destruction of the ships of the enemy. If a great powerful ship can strike heavier blows, and do more complete work, and be more successful in sinking other ships, the fact that a vulnerable blow on the part of the enemy's ship does put out of commission the tremendous power of the big ship, is not an argument for not having the power, because you can shoot a big ship as well as a little one.

As to the waves that would impede a large ship, would not they to a greater extent impede a small one?

I did not have an opportunity to examine the paper before coming to this meeting, and I had to study it as well as I could while it was being presented by its distinguished author. It is a paper which contains the opinion of a man whose opinion should have weight all over the world. The mere fact that some of us do not agree with him will not trouble him.

Sir William White:—Not in the least.

The President:—Are there any further remarks on this paper?

Captain Wm. Hovgaard, *Member:*—The arguments of this paper are set forth in such masterly manner and the arrangement of the subject is so clear and analytical, that one cannot escape seeing the points where difference of opinion exists.

In point XI it is stated that the limit of speed in the big Cunarders in rough weather is fixed, not by size but by considerations of local damage to fittings and navigational appliances as well as dangers to the personnel. Now it appears to me, that although any ship, however large, will have a limit of speed due to this cause, still, this limit must be higher for the larger ship, since its freeboard can be made higher and hence its weather-deck can be on a higher level. Thus, for instance a ship twice as large as the Lusitania should be capable of going up against a certain sea at a higher speed than the Lusitania.

In regard to steadiness in a seaway, the author explains how ships of moderate size may often be more free from rolling than ships of extreme dimensions, in spite of the fact, which is likewise stated in the paper, point XI (*b*), that larger size, if properly utilized, is conducive to greater steadiness and better behavior at sea. The reason of this anomaly is that on account of limitations imposed by harbors and

docks, the naval architects are not free to adopt the most appropriate dimensions in ships of very large size.

It will be seen that this argument against an increase in size is based, not on any intrinsic quality of the large ships, but on extraneous conditions of a temporary character. In fact, when these conditions cease to exist, by a development of the harbor facilities, the increase in size can be made beneficial to seagoing qualities. It appears, therefore, that what we should guard against, as far as this argument goes, is not increase in size in an absolute sense, but a too rapid increase in size.

Dealing first with merchant vessels, I have received the impression from this paper, that the author considers a further increase in size unnecessary and on the whole improbable. I presume the author has here in mind only the near future.

Now it seems to me that an enormous increase in freight and passenger traffic is certain to take place in the future, both on the Atlantic and on the Pacific Oceans, when the American Continent and the East are further developed. This growth in commerce must bring with it a corresponding growth in the entire machinery by which sea-transportation is effected.

Increase in harbor facilities may not always be profitable for the time being, but no great city, district or state can afford to be left behind in the race. Ports which do not now possess the means of improvement may find the means in years to come. On the whole, progress in this direction is likely to be steady, even if slow.

That the size of ships will grow at least as fast as the harbors and docks permit, we may perhaps conclude from past experience, having in mind the probable increase in the volume of traffic. Appliances for loading and unloading ships have been much improved in recent years, and are likely to be still further developed, so as to shorten the period of detention in port.

It seems likely to me, therefore, that in the future we shall see a very great increase in the size of merchant ships, although it may be wise at present to pause for a time until harbors and docks have been further enlarged, and until commerce has developed to still greater proportions.

As regards warships, I agree with the arguments of the author pro and con larger size, but yet I do not arrive at the same conclusion. This may seem paradoxical, but is simply due to the difference in relative weight which I have attached to certain arguments.

The author here advocates in unequivocal terms a return to smaller sizes. There can be no doubt, that the size of large warships has been increased too rapidly in recent years relative to the development of docks and harbors. While in time of peace this anomaly may cause certain inconveniences, it may in time of war lead to dangerous and fatal consequences. It may not be amiss to consider for a moment the case of the Russian squadron at Port Arthur during the Russo-Japanese war. In Port Arthur was found only one dry-dock, which was of too small dimensions to take the battleships, wherefore these ships had to carry out their numerous repairs of under-water damage by means of caissons, under great

difficulties and with great loss of time. Moreover, the harbor entrance did not permit the fleet to pass in or out except at high tide. This fact was taken advantage of by the Japanese, who on one occasion took up a position under cover of the Laotieh Shan hills where the fire of the Russian batteries could not reach them, and at a time when the Russian fleet could not leave the harbor because it was low tide. From this position the Japanese carried out an indirect bombardment of the Russian fleet, which was lying helpless in the harbor. It was mere luck that the Russian ships did not suffer very serious damage on this occasion.

These incidents, well known to naval men, show the danger in a too rapid growth in the size of capital ships, and the advisability of making timely and more liberal provisions for dock and harbor facilities.

For the United States the Panama Canal may soon come to exert a restraint on further increase in beam. Capital ships are fast approaching 100-foot beam, which will leave a margin of only ten per cent. width in the land locks. This margin seems none too large, and a beam exceeding 100 feet will, for this reason, hardly be considered desirable for ships of the United States Navy in a near future.

It seems therefore wise to call a halt in the increase in size of capital ships for the present, but on the other hand, it appears to me undesirable to take a step back to smaller dimensions, as proposed by the author. The greatest need at present seems to me, as I pointed out before this Society last year, a better protection of battleships against submarine attack and an increase in torpedo armament; in other words, a transition from the pure artillery ship to a type partly artillery and partly torpedo ship, both in point of armament and protection. Such a transition cannot take place concurrent with a reduction in displacement; on the contrary, it may be necessary even to sacrifice some of the artillery and part of the armor protection against artillery, in order to gain weight for the development of the submarine qualities and in particular, submarine armor protection, without an increase in displacement.

When the construction of docks and harbors has advanced sufficiently to permit a further increase in displacement, I believe such increase should take place, but always in a conservative manner.

On the whole, it appears to me, that this as well as other limitations to size, such as regards tactical and strategical flexibility, are only of a temporary, yielding character, being ultimately a function of time and of financial resources. The objection to "putting too many eggs in one basket" falls to the ground, if the number of baskets remains the same or is increased, as was actually the case when "Dreadnoughts" were introduced. Size in itself is not objectionable on this ground, but only if it entails a reduction in number. The navy of each country will here find its limit for the time being, but this limit cannot be said to be of an absolute character.

An absolute barrier to the construction of larger and larger units seems to be found only in the eventual stronger development of the submarine means of attack, in particular of the submarine vessel which may some day be capable of driving

the large battleships from the ocean. In my opinion then, the development cannot move backwards, the size of large capital ships must either go on increasing, or this type must be abandoned altogether.

I may add that the above remarks refer only to navies built for ocean service. Navies built for service in more shallow water may already have reached their limit in size.

Mr. W. M. McFarland, *Vice-President:*—This paper, like every contribution of Sir William White to the literature of the profession, is full of valuable information and worthy of very careful study. Although he has told us of the rather unfavorable surroundings when it was written, there is no evidence of this in the paper itself.

The point upon which I wish to comment is to express my appreciation of the careful consideration of the commercial side of the question which Sir William gives. Of course, we all know that he has had a wide experience outside of his service as Director of Naval Construction of the British Navy, but that probably is what occurs to most people when thinking about him. I know from my own experience in the Government service that the commercial side of engineering questions does not receive the consideration there which it naturally does from people whose engineering work has to be done with the constant remembrance that it must result in a profit on an investment.

Until a comparatively recent time our great engineering schools gave scarcely any attention whatever to this aspect of the profit which must result from engineering work if it is to be considered a real success, and I believe I was among the early writers to call attention to this vitally important part of engineering education and training.

I do not think any of us would have considered it a fault if Sir William's paper had dealt almost entirely with the strictly physical side of the question as distinguished from the financial, but it is a great pleasure to me to have this splendid example to put before our students and younger members of the profession where in the discussion of this great question of the limiting size of ships Sir William pays so much attention to the commercial or financial aspect of the case.

The President:—I wish to say, for your information, gentlemen, that I sent copies of this paper to the managers of the Hamburg-American line, the White Star line, the Cunard line, and the North German Lloyd line. The manager of the Hamburg-American line very courteously replied that unfortunately he would be out of town and could not attend this meeting, and did not have any one in his office that could take up the discussion of this paper. The manager of the White Star line has courteously replied he would like to attend, but he would be out of town and had nobody that he could send to discuss the paper. The managers of the other two lines have not up to the present moment responded.

In compliment to the author and the importance of this paper, I have per-

mitted the discussion to go beyond the limits of time, and I must now call the discussion closed, with the exception of giving an opportunity to the author for reply. Any members who desire to add to this discussion, will please submit the same in writing. Sir William Henry White will now have the opportunity to reply.

Sir William Henry White:—Mr. President and Gentlemen, the discussion has ranged over a considerable field, and certain opinions and statements have been attributed to me which cannot be found in the paper? Gentlemen who have made that mistake, in attributing to me opinions which I certainly do not hold—and Mr. Nixon has said that he has only glanced through the paper hastily—will find on reference to the paper that I am strictly correct in what I now say. I will take one case to illustrate what I mean. Admiral Bowles quoted a sentence from the bottom of page 10, from which he made it appear that I considered the upper limit of size to be reached in the Mauretania. If one takes a sentence away from its context, we know, even in the use of Scripture how misleading the result must be. We all remember the case of the man who preached from the text "All men are liars" without mentioning the context, "I said in my haste." When such omissions are made you will see how meaningless any sentence may become, or how it will fail to represent the facts which were really stated. That is exactly where we are at present. I am not suggesting that there has been any intention to misrepresent statements made in the paper, but there has been a disregard of context. What I actually said in the particular instance dealt with and quoted partially by Admiral Bowles was as follows:—"Ocean waves have not grown in size because larger ships have been built; and obviously there must be an upper limit of size, beyond which, so far as maintenance of speed is concerned, further increase in the dimensions of ships will have little or no effect upon regularity of performance of service between terminal ports. I have previously recorded my opinion that this upper limit of size has been reached for the Trans-Atlantic service in the Mauretania and her sister ship, and I will now briefly state certain facts on which that opinion is based." Admiral Bowles omitted to quote the sentence, "I have previously recorded my opinion that this upper limit of size (*i. e.*, the limit of size which will give regularity of passage) has been reached in the Mauretania" and so detached the governing condition from my statement. I hope the position has been made clear and I think it is an important correction. It would be the greatest misfortune, and to me a great disappointment, if any one in this room or any one who reads the paper thought I had used this opportunity for advertising the Mauretania. That is not my object. I only used facts which have been obtained from actual experience with the Mauretania to illustrate a general statement, viz., that increase of size beyond that ship is not necessary to ensure remarkable regularity in Trans-Atlantic voyages.

Now, if any one will read what is said in the paper about the Olympic, they will see I am careful to point out that I do not pretend to give even the roughest estimate of her earning capacity especially in relation to cargo, but I stand on the

fact, which everybody knows, that the great intermediate class of steamers, trading on the Altantic, almost invariably go westward without full cargoes because such cargoes are not obtainable; and I also believe that experience proves that in the average service of such ships employment is not found for their full carrying capacity, although occasionally it may be utilized. The conclusion I was arguing for was this:—a "quick turn round" and rapid loading or unloading, by abridgment of periods spent in port, which are necessarily non-productive, is an essential feature in commercial success, especially for ships of which the first cost is very great.

I will leave other points which have been mentioned, feeling sure that those who read the paper more carefully, will see how cautious I have been, in criticism of existing vessels; and that general statements have been made simply for the purpose of illustrating principles.

The valuable earnings obtained by carrying steerage passengers was referred to by Admiral Bowles. In my paper I dealt chiefly with dead weight cargo capacity, and assumed that ships compared would be kept to dimensions which give practically the same passenger capacity in all classes. The question whether or not immigration into the United States should be permitted is one of high policy and an Englishman, like myself, would not be well advised even to express an opinion thereupon.

Mr. Nixon anticipates the construction of much larger ships and thinks they could be made to pay. I do not profess to be an authority on the subject, but must respectfully beg to doubt their commercial success, unless radical changes should be made in existing conditions of service. But I go further and assert that if vessels of such length were built, and if proportionate dimensions of breadth, depth and draught of water are obtained in their design such as naval architects would desire to have, other people than shipowners and naval architects will necessarily have to concur in the proposition, obviously harbor and dock authorities must be consulted and must agree to provide suitable terminal accommodation. Moreover in regard to the depth of water there must be limits. These are questions certain to require answers, and in the end there will be a decision based on commercial considerations.

In dealing with this matter the shipowner and naval architect cannot be dissociated from the harbor and dock authorities; although the benefit of the nation as a whole will determine action. It is perfectly true, and I have alluded to the facts in the paper, that huge sums have been spent on dock and harbor improvements in many countries, and up to date in most cases more or less adequate returns have been made on this expenditure. I have also dwelt on the fact that some nations, in order to promote the national well-being, considered as a whole, have embarked on large expenditure which yields no direct return as an investment and perhaps never will, although to the nation as a whole it has been beneficial. Here again we are upon grounds of high policy, and outside merely technical or trade interests.

In connection with harbor and dock improvements, Mr. Nixon has spoken of

having formerly limitations of draught to 16 feet, 18 feet or 21 feet of water. We have already advanced to 40 feet of water; but every one who has had acquaintance with such works knows that the cost increases rapidly with increase in the depth of excavation. It is a problem of which I have some knowledge based on experience; and consequently although I sympathize strongly with the desire of my fellow naval architects to have the available depth of water increased as much as possible, I venture to urge naval architects not to act and speak as if the whole world should be rearranged for our benefit. We are only dealing with one item in a great scheme; we must think of the welfare of our nation as a whole, and what will most benefit the community rather than any class in it.

Before quitting this section of the subject let me repeat the statement that I have no desire or intention on this occasion to advertise the Mauretania or to criticize the administrative work of shipowners. These gentlemen are the best judges of the types of vessels to be adopted for various services, and the limits of expenditure they will face in building single ships. My sole desire has been to illustrate and describe principles which, it seems to me, must have important influence on future developments in the sizes of ships.

Coming next to warships, it is obvious that I occupy a singularly difficult position in opposing as I do the large dimensions now in fashion, and recommending a return to more moderate sizes and costs; because I was the man who was criticized nearly twenty-five years ago for introducing monster warships. Some people have forgotten the fact but I cannot. In 1889 I had to defend the Royal Sovereign class which were then the largest warships built; and in thus increasing the size of warships, for which I was responsible, I then believed and still believe I did the right thing.

I am not an advocate of small dimensions. Admiral Bowles spoke of small ships as those in which the magazine were necessarily placed in close neighborhood to boilers and bunkers. Nothing of that kind can be found in any ship designed by me. For many years, I resisted proposals to place magazines and shell rooms in situations where the explosives stored in them would be exposed to the deteriorating influences resulting from high temperatures. To-day's discussion has been diverted into a direction with which personally I have no concern. I am no advocate of small ships. The vague use of such terms as small and large ships reminds one of the old story which used to be told years ago, when I was an apprentice, of a man who said a certain object was of the size of a piece of chalk. We cannot deal with these subjects in such a vague manner; we need clearer definitions. I am not advocating small ships. I am advocating ships so large that they will be capable of maintaining their speed at sea and of fighting their guns in all weathers when an action can be fought. That is my idea of the lower limit of size for battleships. I believe that an undue multiplication of heavy-gun positions in individual ships is a mistake. I argued that matter last year, and my arguments still stand. I disagree with the view that in recommending a return to more moderate dimensions than those adopted in recent warships, one must necessarily place the maga-

zines near to stoke holds. On the contrary I assert that in some of the latest and largest ships recently built the magazines are less favorably placed than in ships of smaller dimensions built previously. I maintain also that if the four commanding positions toward the ends of the ship are occupied by heavy-gun stations, whether each position contains two guns or three guns, it becomes possible to avoid difficulties arising from placing magazines near the stoke holds. In fact a multiplication of heavy gun positions involves an increase of these difficulties. The argument that small ships cannot maintain their speed at sea and cannot fight their guns, falls harmlessly on me, as I do not advocate dimensions so small as to involve these disabilities. My proposal is simply to return to more moderate dimensions and unit cost, because under existing conditions the large number of heavy-gun positions required in even the largest ships, in association with high speed and large radius of action, imposes conditions on the naval architect, which necessarily involve undesirable increase in size, in draught of water, and above all in unit cost. That is my proposition and it has not really been considered in the course of this discussion either by Admiral Bowles or Mr. Nixon.

Further, I say that in respect of both war and merchant ships, that the cost of providing the question of suitable harbor and dock accommodations, for the largest ships built, must be considered carefully; and if it is decided to provide it, the work must be undertaken sufficiently early to have the accommodation ready for use before the ships are completed. If I were concerned financially with harbor and dock accommodations—which I am not, although I have been consulted in connection with many of the works mentioned in the paper—I should say we should always associate with programmes for building of ships (both mercantile ships and warships) programmes for suitable terminal ports. The question of the equipment of ports for the handling of cargoes is also important, but it is not equivalent in importance to that of the provision of adequate harbor and dock accommodations if the dimensions of ships are to be still further increased.

In connection with the great schemes of construction for the British Navy, for which I was responsible, schemes of dock accommodation were concurrently framed and worked out at the time that we were getting our shipbuilding programmes. Never in my time did we have ships completed for which there was not adequate docking facilities. My work at the Admiralty, which involved an expenditure of 100,000,000 pounds sterling on ships for which I was responsible was associated with schemes for docks and harbors, the execution of which involved an outlay of about 22,000,000 pounds sterling and the two works were proceeded with simultaneously.

Passing to the question discussed last year about the multiplication of the heavy-gun positions in the ship, I note that Admiral Bowles quoted from speeches made at meetings of the British Institution of Naval Architects last spring. As I was then performing the duty of President, and sat in the Chair, I did not join in the controversy. It may be pointed out however that although Admiral Bacon said that the biggest ship was the least vulnerable, he also admitted that the biggest ship which could be built could be put out of action and made unserviceable

by a single successful explosion of a submerged torpedo, or submarine mine. The biggest ship might not be sunk so easily as a small ship but she would be put out of effective use for the time in spite of her greater size.

In the discussion which took place twenty-two years ago, when I was the champion of the then so-called monster warship, I used a simile which is well known in military discussions, viz., that a big place, in the military sense, is always a safer place, provided it has an adequate garrison. The same principle holds true in regard to gunfire. A single shell explosion in a large ship is likely to do relatively less damage than a single shell explosion in a smaller ship: but as against under-water attack by mine, torpedoes or submarines, one of the strongest champions of the big ship (Admiral Bacon) admitted that the biggest ship could be put out of action for a time although not sunk by a single successful under-water attack. The crucial point of the discussion in my paper is found in its allusion to recent developments of the under-water attack, which render it undesirable to mass a very large number of heavy guns in one ship which may by a single successful under-water attack be put out of action for that battle. Not a word said to-day touches that argument.

We were told by Mr. Nixon that the axiom "too many eggs in one basket" had been done to death and disposed of, but he did not say why. I also think that further argument is unnecessary, but not in the way in which he thinks it has been disposed of. As certainly as we are here to-day talking over these subjects, shall we see a return to more moderate individual costs for warships. Mr. Nixon, has alluded to wonderful possibilities of advance in the future in a somewhat general manner; if he will kindly condescend to details they can be considered.

Having gone through a long career as a designer of warships and come out on the other side, I do not intend to return to that occupation. I am now a watcher by the wayside; interested in the work being done by younger men in connection with both warship design and merchant ship design; and the last word I would like to say, sir, is that this paper has served its purpose. It was avowedly written in order to provoke a discussion, and it has not failed to do so. (Applause.)

THE PRESIDENT:—Gentlemen, we have certainly had a most interesting discussion on this paper by Sir William Henry White.

MR. MCFARLAND:—The sentiment of the meeting has undoubtedly been quite fully shown by the applause, but for the sake of having it formally on the minutes, I move that the Society extend a most hearty vote of thanks to Sir William Henry White for his most admirable paper.

The motion was seconded by Mr. Charles P. Wetherbee, and duly carried.

THE PRESIDENT:—It looks to me as if the pupils had tried to take a twist out of the schoolmaster, but the schoolmaster is still on top. We will now proceed to the next paper, entitled "Dock Facilities in New York City; Present Facilities, Proposed Improvements and Enlargements," by Mr. W. J. Barney, Second Deputy Commissioner, Department of Docks and Ferries, New York City.

DOCK FACILITIES IN NEW YORK CITY; PRESENT FACILITIES, PROPOSED IMPROVEMENTS AND ENLARGEMENTS.

By William J. Barney, Esq., Second Deputy Commissioner, Department of Docks and Ferries.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

New York City, by the compelling force of the greatest natural harbor in the world, and by its water level connections with the West, has become the central gateway of the western world for European commerce.

As a port, this is largely due not to consecutive planning, nor to continuous port policy, nor to logical development of port facilities, but to the unequalled shore front and great depths of water nature has given.

On the other hand, the port of New York is handicapped in that the city of New York is essentially the financial center of this country. The resident capitalists in ports like Liverpool, Antwerp, and Hamburg are most directly and vitally concerned in their own port's development. Here they put their direct financial interest and energies into their mines, railroads, farms, and factories located elsewhere in the United States. Their New York offices are merely headquarters from which to direct these many industries. Therefore their commanding position and financial prominence do not depend directly upon the immediate improvement and the proper expansion of the port of New York as distinguished from the city of New York. In fact, their interests often require the expenditure of money in the development of the city which might otherwise go to the improvement of the port. Fortunately, the present misuse of the natural advantages are not so fixed as to prevent a proper reorganization of the port for its logical development. Such reorganization and the proper correlation and direction of the future expansion of port facilities will depend for permanency, under our form of government, almost entirely upon public interest and support—especially of such representative bodies of scientific and directly interested men as are here assembled.

Let us first consider the present conditions in the harbor. Recognition and remembrance of the four following broad divisions of freight handled in the port of New York are aids in considering the present facilities, their disadvantages and the proposed improvements and extensions.

The first of these divisions includes the freight that enters and leaves

New York merely as a port of entry for trans-shipment on its way between foreign countries and other parts of our own country. Such freight might well go to Baltimore, Philadelphia or Boston, but is attracted to New York by its land-locked harbor with easily navigated channel approaches and by the greater number of railroads centering in this port, thus offering means for transshipment of cargoes to every section of the country. For brief reference this freight may be termed "Trans-shipments."

The second class comprises the foreign freight coming into the port of New York for direct consumption in the city of New York, especially on the Island of Manhattan for retail distribution therefrom, such as raw materials for factories and the many other articles of foreign make and manufacture demanded by the millions of this city's population. Such freight may be referred to as the "City-Imports."

For the purpose of analysis, passengers must be considered as forming a third class of freight, preferably to be landed in Manhattan because of the hotels, theatres, shops and railroad stations. "Passengers" will be used in referring to this class of freight. Passenger steamers also carry a large part of the second class of freight, "City-Imports," since much of it is packet goods requiring express steamer service. Hence both these classes of freight, "Passengers" and "City-Imports," are largely landed in Manhattan.

These three classes of freight comprise the divisions of commerce found in every great port in the world and are not peculiarly a feature of the port problem of New York.

Manhattan being on an island and Brooklyn and Queens on another, create a fourth class of freight peculiar to the port of New York. Goods from the hinterland for consumption in these boroughs and their own exports thereto come in and go out, as in other cities, largely by the railroads. This freight is given the name of "Railroad-City." This railroad freight must of necessity pass over the bulkheads and piers of these island boroughs. Hence, this "Railroad-City" traffic, by its large water front occupancy, is a big part of the activities of the port, especially in its most congested section—lower Manhattan.

The logical plan for handling these four classes of freight would be to reserve the water front and the immediately adjacent upland for the maritime commerce, that is for the "Trans-shipments," "City-Imports" and "Passengers;" on the other hand, to receive the "Railroad-City" freight and supplies for the city at depots and freight yards so far removed from the water front as not to curtail the maritime development and the cheap handling of maritime freight.

A general map of New York Harbor shows how nature has provided for the proper division of the harbor facilities for the three usual classes of

freight; the "Trans-shipments" and certain "City-Imports" to be handled in various outlying sections of the harbor as South Brooklyn, Staten Island, and, in the remoter future, Jamaica Bay; other "City-Imports" and the "Passengers" to be landed on Manhattan Island as the natural focus with distributing mediums, for the first in its retail shops and wholesale houses; for the second its bridges, ferries and railroad stations.

For the same reason the fourth class of freight, "Railroad-City" consignments, in other words, the railroads, are drawn to Manhattan and therefore conflict with the steamship lines for water front space. This has created the peculiar and complex feature of this port problem.

Let us now consider the present facilities of the port used primarily for handling "Trans-shipments," but also used for "City-Imports." There is to-day one great terminal in New York developed and managed by private interests, namely, the Bush Terminal at South Brooklyn, between 40th and 51st Streets. In many respects, this development, with such improvements as have been introduced since its inception, may well serve as a model for all future freight terminals in the port. The piers are some 1,325 feet in length by 150 feet in width with slips of 270 feet. On these piers are single story sheds. On the deck surface run railroad tracks to the warehouses on the upland adjacent and to a railroad yard in the rear of these warehouses. At the south end of this yard are transfer bridges for a "car-float ferry" to the mainland by which are made shipments to other sections of the country. As a further extension, behind the warehouses and the railroad yard are large industrial and manufacturing buildings where raw products imported from the interior of this country or from abroad are manufactured, and upon order are conveniently transshipped.

Aside from the Bush Terminal's development, there are but two other freight terminals of importance. One, the New York Dock Company, is in Brooklyn along the East River, occupying various sections of the water front from Main Street to Van Brunt Street. This terminal offers both docking and warehousing facilities, and certain sections are connected by a belt-line railroad.

The remaining terminal is the American Dock & Trust Co., on Staten Island. This terminal is unique in that it possesses direct railroad connection with the mainland by a bridge over the Arthur Kill. It is essentially a trans-shipping terminal, and, owing to the railroad ownership of the surrounding property, its expansion seems practically limited for the present.

The trans-shipments from the two island terminals in Brooklyn, the Bush Terminal Company and the New York Dock Company, are made to the mainland in two ways. Where goods are to be shipped directly from the steamer by railroad to the West, they are usually unloaded from the

steamer into freight lighters moored alongside. These lighters are then towed to the Jersey terminals of the trunk railroads. On the other hand, goods temporarily stored in the adjacent warehouses, upon being selected for shipment to the West, are placed in freight cars which are run on the belt-line railroads or switches to transfer bridges, an essential part of these island terminals. There they are placed on car-floats and in the same manner as the direct shipments are transferred to the Jersey railroad terminals.

Aside from these terminals, little has been done in an organized manner for "Trans-shipments." Individual piers require the most direct interchange of freight between steamers and railroads, since they afford practically no facilities for storage. Often steamship lines carry various classes of cargo, both "Trans-shipments" and "City-Imports," or again freight is secondary to passengers, hence at piers in Manhattan are found steamers handling "Trans-shipments."

The port authorities have in view the installation by the municipality of terminals for "Trans-shipments" and "City-Imports" in addition to those now provided by private enterprise.

Such an extension is proposed for South Brooklyn, from 36th Street north around Gowanus Bay and over the site of the present so-called Brooklyn Basin. This development will provide long piers from 1,775 feet in length down to smaller piers from 200 to 300 feet in length for small craft and barges at the head of Gowanus Bay. Back of these piers are to be erected warehouses. Railroad spurs are provided on the piers with adequate switches to the warehouses and with connections to proper switching yards, this track system to be connected up by belt-line tracks to a classification yard sufficiently large for the proper assembling and quick handling of through freight to the West. This yard is to be located to the rear of the present Brooklyn Basin section. From this yard cars will be sent to transfer bridges in the neighborhood of Conover Street for transference on car floats to the mainland.

A similar municipal improvement is planned in the section of the water front immediately south of the Bush Terminals. Thus the municipality and private enterprise will make this section of the water front, from the neighborhood of 60th Street north to Conover Street, one great freight terminal as distinguished from mere pier accommodations for ships. Access will be had through a channel 1,200 feet in width dredged to a depth of 40 feet at low water.

A development is proposed for the east shore of Staten Island between the American Dock Company and approximately Clifton Avenue. In this section will be built piers about 1,000 to 1,350 feet in length, 200 feet in

width, with slips 300 feet wide. Back of these piers will be reserved a sufficient strip of upland space, some 325 feet in width, for warehouses, railroad connections and other features required by an up-to-date water front freight terminal.

These outlying developments are planned essentially for "Trans-shipments" and "City-Imports" but with the anticipation that industrial and manufacturing centers will be developed in the immediate hinterland.

Still further, a plan is proposed for Jamaica Bay. The immediate improvement of this Bay under appropriation from the United States Government and from the city contemplates a 15-foot channel with certain local dock improvements which will tend to build up industrial and manufacturing centers. As these future centers grow and justify further expenditure, the whole bay is to be developed into one great freight terminal and commercial area for manufacturing industries such as are now carried on in Manhattan under the great handicaps of expensive ground rents, unsanitary conditions, slow truckage hauls, etc.

In connection with this presentation of the present water front freight terminals in the harbor and their proposed extensions, the present lack of mechanical equipment is worthy of note. Practically no piers in New York Harbor aside from the "Chelsea Sections," are equipped with cranes and other mechanical freight-handling devices. Doubtless this has been due in a large measure to the fact that until recently congestion has not made imperative the intensive use of any section of the water front. Further, piers of the present width do not permit two or three-story sheds for the handling or temporary storing of freight, since all freight on a pier must of necessity pass out at the bulkhead through the narrow entrance to the pier. Hence, if from two or three-story structures great quantities of freight were being delivered at once, prohibitive congestion would result. Therefore, the absence of more than one-story sheds, and, further, the moderate rise and fall of tides have led to the handling of freight from steamers to piers, and vice versa, largely by mechanical appliances on the steamships themselves. In the proposed plans for the outlying sections, especially in the Jamaica Bay and the Staten Island districts, provision is made for piers of sufficient width to allow a wide, open driveway down the center; freight sheds to be on either side between the driveway and the edges of the pier. These piers will be practically equivalent to quays or bulkheads. On such piers it will be practicable to build two or even three-story sheds, since the freight accumulated from steamers can be readily passed out through the entire length of the driveway side of the shed. For the handling of cargoes to the second and third stories of such sheds, mechanical devices will of

necessity be required. There are many engineers who advise the adoption of the telpherage system or a series of overhead traveling conveyors in the pier sheds themselves for the handling of even miscellaneous freight and mixed cargoes. While the few telpherage experiments so far tried in this country leave as a debatable question the final superiority of these mechanical methods of handling cargoes over the present hand labor with trucks and individual wagons, still the Department is carefully considering plans for a pier shed fully equipped with mechanical and automatic freight handling appliances.

The Department has not been unmindful of the need for small local improvements where large terminals are not required or not possible from natural limitations. It is proposed in many sections of the harbor to replace individual piers by small terminal units. Such a terminal will call for one or two car float transfer bridges; and on the upland, short sidings and convenient freight houses. Between the different tracks will be driveways accessible so that trucks may load and unload directly alongside freight cars. This same water front would ordinarily accommodate only 1 or 2 piers. At these piers only 2 or 4 car floats could be moored. Consequently only 24 or 48 cars a day could be handled. But under this terminal arrangement, this same length of water front will permit the loading and unloading of 125 freight cars per day. The improvement here shown is intended at Nott Avenue, Borough of Queens. It is proposed that the city shall build this installation. Then, under the recent Terminal Act, a company is to take it over for operation upon a sufficient rental to pay for the interest on the investment and amortize the bonds.

The large "Trans-shipment" terminals do not attract the passenger lines or packet steamers because such terminals require large tracts of upland and therefore must be located in sections of the harbor remote from the central congested district of Manhattan. On the other hand, the "Passenger" service and a large part of the "City-Imports" have centered on the Manhattan Island water front. On this water front, the East River and the Harlem River have been practically relegated by natural causes, swift tides and narrowness of the fairway, to coast lines, railroad floats, canal barges, and other small craft.

On the North River, the upper sections of Manhattan, where developed and not occupied by parkways, are at present largely occupied by river lines, small craft and barges handling building materials and coarse freight. The lower Manhattan water front on the North River is a natural location for the large passenger and packet express steamers, since their passengers and cargoes are destined particularly for Manhattan; the former to its hotels,

shops, theatres and railroad terminals, the latter to its wholesale and retail houses, factories and adjacent railroad piers.

There is one large Trans-Atlantic passenger and packet freight installation in the port of New York; the Chelsea Section between 12th Street and 23d Street. It was built by the city and then leased at low rentals to the ocean lines. These piers are from 800 to 825 feet in length and 125 feet in width, with 250-foot slips of sufficient depth for steamers of 40 feet draught. Aside from six other piers at various locations, these seven full piers and two half piers are the only double decked docks in the port of the city of New York. The lower decks are used for the handling of cargo; the upper decks are large passenger terminals.

At the time the Chelsea Section was built, piers 825 feet in length were regarded as fully adequate to accommodate any steamers that might be built in the future. Now the port authorities are confronted with the problem of the Olympic and Titanic some 882 feet in length, with promise of steamers still longer to come. This enormous stride in the length of steamships is doubtless due, aside from the progress in naval architecture, to the removal of channel restrictions through the Government's dredging and maintaining the 40-foot Ambrose Channel to the sea.

Unfortunately this Trans-Atlantic improvement is located at the narrowest point in the lower fairway of the Hudson River. Therefore, after careful consideration, the Secretary of War has refused any permanent extension to the pierhead lines; but has granted to the city a temporary two years permit to lengthen two of these piers for the present accommodation of the Olympic and Titanic. Consequently the port authorities in the near future must provide piers of 1,000 to 1,100 feet in length in some other location.

Above the Chelsea section as far as 60th Street, of the 36 piers, 6 only are used by steamships and 14 for open wharfage, dumping facilities and other miscellaneous forms of river traffic. The 14 other piers are occupied by the railroads. South of 23d Street, aside from the Chelsea piers, 18 piers only are now occupied by steamship lines in the coastwise service; 3 small piers and 2 large ones are open for general wharfage and the remaining 27 piers are occupied by the railroad companies. Therefore of 95 piers on the North River below 60th Street, 41 piers, or nearly one-half, are occupied by the railroad companies or the "City-Railroad" freight.

Excepting the New York Central, the great transcontinental railroads reaching this port terminate on the Jersey shore. In the morning freight cars on car floats are towed over from the Jersey side to the various piers of the different railroads in Manhattan. The car floats are moored in the

morning alongside the piers, and the freight in the cars is unloaded onto the piers, on many piers so closely as to make it difficult for the truckmen and delivery companies of the various consignees to reach their particular shipments. In the afternoon these car floats are pushed to the bulkhead proper, where they receive the outgoing freight delivered during the day at the various bulkhead sheds along the river. The loaded cars are then towed back to Jersey and made up into the "Westbound" freight trains.

This method of handling the "Railroad to the City" freight results in a floating freight yard from the Battery north to 23d Street. As a consequence of the immediate importance of the food supplies, manufactured products and other freight handled by the railroads in this manner, there has been a gradual crowding out of the steamship lines, both Trans-Atlantic and coastwise, until now of all of the piers for maritime commerce between the Battery and 23d Street, 40 per cent. are to-day used for the floating freight yards of the railroads.

This water front is imperatively required by the growing maritime interests in the port. On file with the Dock Department are many applications from steamship lines which request piers only in this section of the water front, owing to the requirements of their business. Further, this railroad occupation of the water front by floating freight yards is the great barrier, if continued, to the early construction of piers for vessels of the Titanic and Olympic class and other still larger ships. Such piers, unless a radical upsetting of the passenger and packet service is attempted, must be located on the North River in Manhattan. Piers, especially for these larger ships, should not be located any farther up the Hudson River fairway than absolutely necessary. The farther these large ships have to proceed up the river the more difficult becomes navigation owing to the increased number of river craft, especially from the ferry service concentrated at 23d Street, and the farther removed are their piers from the wholesale houses, warehouses and factories in lower Manhattan—the destination of the larger part of their packet freight. Therefore any extension of the Chelsea Trans-Atlantic terminal should be to the southward. A further reason for this is that to the southward natural conditions lend themselves to longer piers. The bulkhead line south from the Chelsea section to the Battery makes an inward curve or bow. The pierhead line now closely follows this curve. While the War Department has refused a permanent extension of the pierhead line in the Chelsea section, it may be fairly assumed that no objection would be advanced to making the pierhead line from the southerly pier in the Chelsea section to Pier "A" at the Battery a straight line, since the fairway of the lower Hudson rapidly widens. Then in

this section, between say Franklin and Christopher streets, there can be built piers from 1,000 to 1,050 feet in length. But just here are now the railroad piers and the floating railroad freight yards of car floats. These railroad cars and their freight must come into New York, but the loading and unloading can be done elsewhere than at the water front; whereas, ships' cargoes can be unloaded and loaded only at docks and piers. Therefore, to provide properly for the steamship lines and yet to conserve the railroad facilities of the city, freight cars must be given a common point of entry to the city upland in a less congested district of Manhattan with track connections into the downtown wholesale and business districts.

It is therefore proposed to install a series of car float transfer bridges between 30th and 40th Streets on the North River, and there to concentrate the delivery of all car floats now occupying the water front in lower Manhattan, and by means of ramps or inclined planes to bring these cars from these car floats up onto an elevated railroad to run south from 25th Street along the marginal way. It is further proposed, by means of elevated sidings from this elevated railroad, to place these cars into the second story of large freight terminals or warehouses, etc., on the east or inshore side of West Street. The freight is there to be unloaded onto receivng platforms either for storage or for delivery at the street level to trucks, etc., by chutes, elevators, or other mechanical devices. The reverse procedure will handle outbound shipments. At present the east side of West Street is largely occupied by a poor class of buildings. The replacement of these buildings by large up-to-date freight terminals will so enhance property values here as largely to compensate the city for any expense involved in the proposed improvement. Additional returns will come from the various railroad companies using this union elevated belt line, these charges to be sufficient to pay interest, overhead charges and amortize the sinking fund of the elevated construction itself.

This terminal system is to be exclusively for the handling of the "City to the Railroad" freight. No connections, while possible, are planned between the marginal elevated railroad and steamship piers as it probably always, or at least for many years, will be cheaper and quicker for the "Trans-shipment" to be made direct from the steamers overside to freight lighters moored alongside.

In addition to practically doubling the present maritime capacity of the central part of New York Harbor, by removing the railroads from this needed water front, this elevated freight marginal railroad will also serve to solve a most pressing civic problem, namely, the removal of the New York Central's tracks from the surface of 11th Avenue and the marginal

way. For it is proposed to continue this elevated railroad north of the car bridge installation at 40th Street to the New York Central yards at 60th Street, thus incorporating into the terminal system Manhattan's all-rail freight connection with the West.

As the final step in handling this "Railroad to the City" commerce, a large city freight terminal yard is proposed between 25th and 40th Streets. Provision is made in this manner for the proper handling of the "Railroad to the City" freight away from the water front, as is done in practically every other city or port of the world. A large stretch of water front south of Gansevoort Street will then be open for more strictly maritime use. The pierhead line will be straightened out and piers from 1,000 to 1,100 feet installed. It is believed by the Department that such an installation and reorganization of the port facilities will more than handle the prospective growth of maritime commerce for many years to come and also meet and solve the difficulties presented by the increasing length of Trans-Atlantic steamers.

For the accommodation of the Olympic and Titanic class of steamers during the years required for this reorganization, two 1,000-foot berths are planned between Pier 53 of the Chelsea section and Pier 52 to the south. At present this water front is occupied by a market fronted by 3 short open piers. After the market and present piers are removed, the upland can be dredged back for some 700 feet. Thus will be provided a slip of sufficient length and width for two 1,000-foot steamers, with a half pier on each side for the handling of cargoes.

Eventually the North River-Manhattan section of the port of New York may extend farther northward. Without disturbing the proposed railroad installation between 30th and 40th Streets, the water front north of 72d Street in the distant future may provide further accommodations for Trans-Atlantic and coastwise steamers. North of 72d Street, outshore of the present or future tracks of the New York Central, the bulkhead line permits of filling in and reclaiming a strip of land from 100 to 200 feet in width. The steep slope of Riverside Drive makes possible an artistic roofing over both of the tracks and this reclaimed land. The deck of this roof may constitute an extension of Riverside Park. Beneath this covering may be made driveways connecting with the different streets cut through to the water front, and platforms and sheds for the handling and receiving of freight may be installed. The water front of this reclaimed land will form a practically continuous quay for many miles, affording berths for numerous steamers even of the large Trans-Atlantic class. Such an improvement will not only serve the distant future needs of the port along the North River but also conserve to a large measure the beauty of Riverside Drive.

In connection with providing further facilities for large steamers at Manhattan, there must not be overlooked provision for the transient and smaller craft. In Manhattan below 18th Street, the so-called open wharfage or piers where canal boats, river steamers, tramp freighters and such craft may occasionally be berthed, are practically limited to 5 piers. The comparatively high cost in Manhattan of building materials, structural iron, and coarse freight is due in some measure to this lack of open piers, which often necessitates long truckage hauls from the more remote sections of the Island. In the proposed reorganization of the port such open piers will probably be provided at not more than half mile intervals in congested sections.

As stated in the opening of my address, the great problem of New York Harbor authorities at present is not the lack of natural resources or the overcoming of engineering difficulties but rather to organize the separate piers and to correlate the many disconnected developments, and to end the confused use of the water front. Any betterment of port facilities must conform to the demand of the times, namely, systematic and effective organization. In other words, future harbor plans must be governed by the same change that in private business is merging small disconnected companies into large corporations. Port authorities must cease to develop the harbor from the standpoint of individual piers used regardless of their neighbors, and must plan all future improvements not only for sections of the harbor but for the harbor as a whole, so as to make the port one organized connected terminal. It is toward this end that the present port authorities in New York are working. As in the reorganization of modern business, individuals and smaller companies have suffered, so a departure from present conditions and past customs of port development will entail seeming hardships upon individual companies and individual sections of the harbor. Therefore, antagonism is aroused and ultimate success depends largely upon a broadened outlook of all concerned and a willingness to concede much for the ultimate greatness of the port of New York, also upon stout assertion by the City of its trusteeship of the water front for its best use as a whole.

A brief address can give only in outline the present conditions, their disadvantages and the necessity for improvements and the proposed methods of making them. Therefore, I have left untouched the equally large subject of port organization from an administrative standpoint. More important even than plans, is a stable form of port administration capable of a continuous port policy and of carrying out of plans after they have been once adopted. For the present, the responsibility for a continuity of policy rests not in the changing port authorities but in the public and more especially

in organizations and bodies of men directly or scientifically interested in seeing the proper development of New York Harbor.

To the end that all who have sufficient interest may become fully cognizant in detail of present conditions and proposed plans, Commissioner of Docks Tomkins has issued in the last year some fourteen reports for distribution. These reports set forth fully not only matters upon which I have touched but many other phases not here mentioned. These reports are for public distribution and should any of you gentlemen here, either as individuals or as an organization, desire to study them, I shall be glad to see that these reports are sent to you at an early date, and in turn I request the benefit of your criticism and your support toward the proper working out of the future growth of the port.

DISCUSSION.

THE PRESIDENT:—The paper before you for discussion is a very interesting one, which was read before recess by Mr. W. J. Barney on the harbor facilities for New York, and discussion on that paper is now in order. We will be glad to hear from any gentleman.

COMMODORE J. W. MILLER, *Associate Member of Council:*—The two able papers read during the morning session, aside from their general interest, were most instructive as complements the one to the other.

Sir William White's warning to naval architects of the futility of building larger ships until existing channels were deepened to float them was timely. The cost of making harbors for over thirty feet draft being a tax upon the people at large far exceeding any increased profit to the ships which could enter the few ports of the world, thus improved at prohibitive expense.

Even to-day, the great speed of the Atlantic greyhounds is partially neutralized through waiting for tides at ports like Liverpool.

Mr. Barney in his paper, showed the difficulties incident to proper dock facilities for the latest ships of large tonnage here in New York. If bigger ones are to follow let us ask the questions: Can they be accommodated? What delays will ensue off Sandy Hook or in the lower bay? What other harbors are open to them elsewhere?

Mr. Barney's forcible recital of the details necessary to correct our water front are most instructive, yet there are one or two points which are worthy of discussion.

As long as the dry-goods warehouses and other kindred stores remain in the lower part of the city, both steamship lines and railroad piers must be conveniently situated for the transfer of products from the New England States, otherwise the

industries of the East will more and more drift directly from Boston to the West. You cannot segregate the facilities of the water front, or separate our coastwise commerce either by rail or steamship from the nearby warehouses. They are interdependent, one upon the other.

The second point I would mention is the absolute necessity of New York having a proper deep water outlet to the east via Long Island Sound. The Metropolitan City of the United States needs a double exit to the sea both for war and commercial purposes. It can be accomplished at minimum expense, considering the advantages to ensue, by widening and deepening the channel through Hell Gate as far eastward as the Brothers. When that is accomplished, much of the local business can be handled both by the existing railroads and by future docks in the neighborhood of the Harlem, while battleships will have a double means of approaching to and from the sea.

There is till one other point I would like to touch upon, and which is referred to by Mr. Barney.

Granting that we are a commercial people, and need many dock facilities, we are also citizens of the chief city of the western continent. As such both from patriotic, state and civic pride, we should do more to beautify our water front. This can be accomplished along Riverside Drive, giving to the populace a playground without interfering with the present park system; simply by filling the shoals now unkept and unimproved. There, also, should be built a fitting reception pier and water-gate to receive distinguished naval officers and to provide accommodations for our enlarged navy. Between 72d Street and 125th Street, should be placed all the marine public institutions.

The need of such an artistic improvement was shown some few weeks ago when our own large fleet, being second only to one in the world, was anchored in the Hudson River. The people, not only of our own State, but of the whole country, endeavored to obtain access to our war vessels at a spot where no proper means was supplied for them to do so. While we are all advocates of commercial development, we also believe that it is essential for a great marine port, in order to retain its supremacy, to enhance its artistic possibilities. The question has been agitated ever since the Spanish-American War by various organizations, such as Columbia University, Fulton Monument Association, the Navy Alumni Association, Naval Militia, and the New York Central Railroad; all of whom are ready and prepared to do their share.

May I express the hope that all who hear me will assist in this laudable endeavor.

Mr. W. D. Forbes, *Member of Council:*—This paper suggests to me a story told of Sir Alexander von Humbold. He was invited to a dinner and was seated on the right of the hostess, and in the good old German fashion she was to do the carving. She turned to him and said, "Sir Alexander, I understand you are the best educated man in the world; please tell me all you know while I am carving this fowl."

It seems to me we have to consider a great problem in a very short time. It is a

satisfaction to know the problem is being developed as it is under able management, but if you will notice, gentlemen, the paper is about the Harbor of New York, but the State of New Jersey is left completely out of consideration. Now, I am a little proud of the State of New Jersey, and I think if the Department of Docks and Ferries would look over to the west shore they might see something of interest. It may have been considered, and I would like to ask whether it is contemplated to use the Jersey shore in the project, because back of the Jersey shore lies the whole United States. This section is not by any means the greatest part of the United States. The eastern part of the country the harbor of Boston can take care of, but beyond the Jersey shore the whole distribution of the United States starts and it seems to me that this fact should be looked into with care in considering the harbor of New York.

THE PRESIDENT:—Are there any further remarks on the Paper?

MR. F. L. DUBOSQUE, *Member of Council*:—While I did not intend to say anything on this paper I would like to make a criticism of one statement contained therein: "The logical plan for handling these four classes of freight would be to reserve the water front and the immediately adjacent upland for the maritime commerce." It seems to me the logical plan is to do just the contrary. The effort of the Commission seems to be to take care of ships bringing passengers and freight to New York, without regard to other classes of freight, and while it is true that the railroads do occupy a large part of the river front the reason is not very hard to find. The policy of the city of New York has been to give the steamship companies a long time lease with all kinds of facilities at a very low cost, but to give to a railroad company a lease extending not over a year at a most exorbitant charge and then compelling them to do all the improvements at their own expense. If the railroad companies will bring to and take from New York so much more freight than the steamship companies it seems as though the logical conclusion is not to cater to the steamship freight, but to that class of freight requiring the most facilities.

I feel there is ample room on the Hudson River to accommodate the passenger travel and the express freight coming in steamships to New York City, and also to take care of the railroad freight without any such elaborate arrangement as here suggested, and this thought is encouraged by the fact that the most profitable and satisfactory arrangement for taking care of exclusively steamship freight, as pointed out by Mr. Barney, is now being pursued at the Bush Terminal in Brooklyn, and if the Commission would lay out a scheme that would segregate the exclusively steamship freight from the passenger and express matter, and locate the steamship freight at points where the land is not so valuable, as has been done at the Bush Terminal, and then give up to the railroads a very much less portion of the river front than now occupied with long term leases, they would be encouraged to go to the expense of putting in modern mechanical facilities for handling railroad freight and a solution of the problem would be more profitably reached.

The result of the scheme suggested here in the opinion of a great many practical people who examined it is that it will increase the cost of the delivery of freight by railroad companies to the city of New York by at least 25 cents a ton, and some people think also that the scheme is somewhat impracticable.

SIR WILLIAM HENRY WHITE, *Honorary Member*:—Mr. President and gentlemen, you will understand that I would not be guilty of the impertinence of saying a word in regard to the port problems of New York. Those who have to regulate and control the traffic of this harbor are the best judges, and in speaking of those who have to do that work I am thinking of those who are interested in the problems of the port, as shipowners, merchants, and in any other way, as well as the Commissioners.

Perhaps our experience in England may be of some service to New York in this matter. Our experience convinces us that the most satisfactory way of developing the resources of any port is to constitute a local authority of an advisory nature which shall consider and discuss questions of policy, and to make that authority representative of all the interests affected. The Mersey Docks and Harbor Board is such a body. A previous speaker has pleaded the cause of New Jersey, in connection with the Port of New York and it may be of interest to state that when there was a separate authority on the Cheshire side at Birkenhead from that which existed at Liverpool, there was a natural tendency to develop chiefly on the Liverpool side. Although docks had been independently constructed at Birkenhead they were not fully utilized until a single port authority was put over both sides of the river Mersey. The constitution of such an authority in England is done by Parliamentary powers, an Act of Parliament being passed when an authority is set up. On the Tyne, where some of the greatest works in aid of navigation and commerce have been carred out, on the Clyde, the Tees, the Humber and indeed everywhere in the United Kingdom the system prevails of having local boards, not of an executive nature, but of an advisory nature, with a settled policy. Such Boards naturally give fair consideration to the claims of all who are interested in the business of a port. With these boards are associated professional men, civil engineers, traffic managers, men skilled in details of business, and others, whose united efforts make the scheme work. I cannot imagine that even the best informed executive, apart from the special knowledge of those whose interests are affected, can suffice. Until recently we had, in the Port of London and the River Thames, a number of private companies owning docks and competing with one another. The way out of that condition of affairs was found by an Act of Parliament which has constituted a new Port of London Authority. To this authority was given by Parliament power to raise funds and frame schemes of improvement for the Port of London as a whole. That is what is wanted in any port if the best use is to be made of it.

THE PRESIDENT:—Are there any other gentlemen who wish to discuss this question? If not, I will call on Mr. Barney to close the discussion.

Mr. Barney:—I will take only a moment. I can see the application of that turkey story, because to attempt to present the problems connected with New York Harbor in a single paper is a pretty large subject.

Speaking of the river-gate at 116th Street, for example, that is contemplated in the plans of the Dock Department in connection with the Riverside Drive development; and the proposed ultimate commercial development, shown on the slide, is simply a suggestion of what could be done at some future time when commerce invaded that section. As a case in point, the old Washington Square residents rebel at the idea of the development of Washington Square as a business center, but that is coming to pass. The present idea of the Dock Department is that the Riverside Drive shall be what it is—a park for the people—but the development of it is contemplated in such a way that the future commerce can come in there with the least injury to the artistic surroundings.

In the same connection is planned a yacht basin at about 158th Street. At present, along Riverside Drive, there are innumerable yachts scattered all along the river front which must have proper consideration. But such details cannot be covered in a general paper.

One of the gentlemen spoke about leases. I think I am in a position to state that he is misinformed both as to the past and present policy of the city in the matter of leases. The past policy of the city has been to make leases for from ten to twenty years, not only to steamship companies, but to the railroad companies. Practically forty per cent. of the piers I spoke of are now tied up in leases of ten to twenty years. These will make it difficult to go ahead with the improvements which are contemplated.

That is the past policy of the City, both as to steamship lines and railroad companies. The present policy with regard to leases is, as the present leases expire, to make the leases from year to year, not only for the railroads, but also for the steamship companies. The Maine Steamship Company, the Bermuda Steamship Company, and other steamship companies now occupy their piers under one year leases. The Pennsylvania Railroad Company has only a one year lease for its pier. The idea is to loosen up the situation as fast as possible to get it in control of the City, and to retain control so acquired at least until a definite port plan is adopted.

The point which you must bear in mind in connection with the traffic in Manhattan is this—that if the railroads to-day installed on their piers freight handling devices to increase the capacity of the piers fifty per cent., and still occupy the water front with floats, in five years the conditions would be the same relatively as they are to-day, since the railroad traffic is increasing at the rate of 10 per cent. per year.

Some critics of Commissioner Tomkins say that he is trying to disturb the railroad and city freight, and is in a way favoring the maritime commerce. Commissioner Tomkins is the best friend all the railroads have to-day in that respect. The New York Central Railroad Company knows that its tracks must come up sooner or later from Eleventh Avenue. There is only one practical way to dispose of them, and that is to put them on an elevated structure and give them connections

downtown. The New York Central to-day stands ready to build that railroad with its own money and take it over as a practical monopoly for the transportation of freight on West Street, free from competition, but Commissioner Tomkins is standing out to give the New Jersey Railroads an opportunity later, when conditions make it imperative, to come in on this Municipal Belt Railroad—this for the best interest of the City.

In this connection, Mr. Miller presents a misconception of the operation of this elevated freight system held by many, namely, that establishing a point-of-entry carfloat installation above 23d Street would disturb the interchange of freight between the railroad and various downtown wholesale and distributing houses. The very reason for the existence of this marginal elevated railroad is to permit freight landed at 23d street to be brought to a point as near to the consignee as possible before being removed from the freight car.

As noted in the paper, it is part of the plan that the entire downtown section between West Street and Washington Street south of Gansevoort Street may be occupied by freight-receiving and distributing terminals where freight cars will be unloaded and loaded at points near to the downtown consignees and shippers.

Mr. Miller also touched upon another much discussed point, the moving of the ships plying between New York and New England points to the East River. This subject, in itself would afford ample opportunities for prolonged discussion, but briefly, one of the objections is that much of this New England freight is brought to New York for trans-shipment to Transatlantic lines and coast lines going south and to railroads going West. Consequently they should be on the North River to avoid long truckage hauls across the City to the various piers of the Transatlantic and coast lines located on the North River.

In connection with Mr. Forbes' suggestion as to possibilities offered by New Jersey, it might be well to know that there has been appointed by the Governor of the State of New York and the Governor of the State of New Jersey, an Interstate Commission of six members, three from each State; one of those representing New York State being Commissioner Tomkins.

The condition to which Mr. Forbes calls attention is one not unfamiliar in other ports where artificial differences of government prevent proper development of port facilities along the most natural lines, as, for example, in the Port of Antwerp where the development is practically confined to the Antwerp side owing to the river being the dividing line between the County of Antwerp and the County of Flanders.

The appointment of the Commission above referred to, is probably one of the most important steps in recent years in the conservation of the commercial advantages and the development of port facilities of the harbor of New York as distinguished from the port of the city of New York, and such Commission should have thorough co-operation and support of all business men along the broadest possible lines.

Mr. DuBosque advances an argument which has probably done much to retard

the adoption of any comprehensive port plan, an argument which at bottom advances the old principle of *laissez-faire*. While it is true that railroad shipments in and out of Manhattan, both as to value and immediate necessity outweigh, certainly to the local community, in importance and value the freight handled by steamship companies, yet such freight need not be handled in floating freight yards on the water front, thereby imposing an unnecessarily heavy handicap on the natural development of the shipping interest of this port. In other words, Mr. DuBosque proposes to permit the railroads almost exclusively to occupy the North River water front and to continue to do business in a manner which does not permit of the quickest distribution and receipt of freight once landed and results in the thoroughly congested condition now found on West Street, making it almost impossible for a shipper to deliver and receive more than one dray load of freight per day.

At the same time, he would compel steamship interests to do their business under the handicap of receiving and unloading freight for Manhattan in uptown sections, entailing extra cartage and other expenses incident to remoter locations.

The plan proposed by Commissioner Tomkins does not propose in any way radically to disturb the present centers of freight-receiving and freight-shipping on Manhattan, but merely to readjust and coordinate access to these freight centers so as to permit both railroads and steamships to do business under the best circumstances.

To pass to one other point. I am not only much pleased that Sir William Henry White honored the paper with a notice, but I am glad he brought home to our attention what is the basis of the whole port problem in New York, and that is port administration. That is the crux of the whole problem in New York and always will be—to have a proper administration of the port. These matters should be administered by a continuing board. The Commissioner of the Department of Docks and Ferries usually holds office for a comparatively brief period and it takes him some time even to become familiar with the largeness of the port problems which confront us here in the city. At the end of four years, the chances are that he will leave office, and someone else take it to learn the problem over again.

You must have a port authority, and what the present Commissioner is trying to accomplish is exactly what Sir William suggested with relation to the Mersey Harbor and Dock Board, where certain members of that Board represent the municipality, and certain members represent the commercial interests concerned with the administration of the harbor and docks of Liverpool. The Commissioner here is doing that, in an unofficial way, by going to our Chamber of Commerce, and the various Boards of Trade, and asking them to appoint Committees to confer with him. He is trying to make the Port policy of New York City the policy which will best represent its commercial interests.

H. L. DesAnges, *Member* (Communicated):—The subject presented by Mr. William J. Barney, Esq., Second Deputy Commissioner, Department of Docks and Ferries, is of exceeding importance to the shipping interests of New York Harbor;

its scope is so wide and far-reaching, that I believe this subject should be given more than ordinary attention. That part of it which refers to the outlying districts, while comprehensive, will not have a serious effect upon those localities, which being comparatively new, will readily adjust themselves to the conditions; while that along the North River will affect a long established section, and to make the changes suggested will upset not only those directly interested, but trade in general.

New York City has regulated itself so that communities of interests have adjusted themselves naturally to the environments and ends. A readjustment of this situation, I am of the impression, would be very serious in its effect. Freight and business interests assemble themselves largely in the lower part of New York City; the large hotels and commercial houses are traveling uptown, to which center it would seem that the steamships would be naturally attracted.

The Chelsea improvement was no doubt a wise move in this direction, and it would seem to me to be the logical thing to continue those steamships already established above 23rd street, and that the development of Piers to meet the demands of not only vessels of to-day, but possibly those of the 1000-foot class, should be carried on to the north, as would seem to be the natural trend.

It is true that the narrowest point of the river is about opposite the Chelsea improvements, and that one of the arguments for moving the steamships to the downtown section would be to take advantage of the increasing breadth of the river, this having considerable bearing upon the subject. It is my belief that it will be found that the river widens above the Chelsea improvements, and therefore there is greater opportunity for the establishment of long piers above 23d Street than there would be below, for the reason that the Jersey shore in its present state is practically unimproved in that section which would admit of changes in the harbor lines.

There is a very serious objection to moving the freight transfer stations to a point above the Chelsea improvements for the reason that many of the Trunk Lines entering New York have their terminals below the Chelsea improvements on the Jersey shore, and it would mean to invite difficulties in navigation due to the diagonal crossing of the river which would be consequently necessary, and the concentration of a larger number of float movement above the Chelsea improvements would increase the hazard of shipping, including the movements to and from the 23d Street Ferry terminal. It is also believed that the concentrating of the steamships below the Chelsea improvements would be less desirable, not only to the steamboat interests, but to the patrons of these interests who would find the lines less accessible below 23d Street, than they would if they were placed above 23d Street.

It is therefore believed that the best policy to be pursued would be to continue the freight transfer in that section of the boundary beginning at, or near Pier 1, North River, making such readjustment as might be necessary to concentrate them between Pier 1, and Christopher street. And it is believed that the steamships could best serve the future needs, and could best accommodate the demands of the public by being continued in a line above the Chelsea improvements,

I am largely in favor of the adoption of a permanent, central, non-partisan, Harbor Board, whose duty it would be to handle all such questions, relieving the Dock Department of this duty. The Dock Department, being more or less political, is susceptible of changes at each change in the City government. A Harbor Board, being non-partisan, would formulate a permanent policy governed by public opinion, and would in this manner determine the best plan for the formation of the city's water front.

Mr. Barney (Communicated):—The first point made by Mr. DesAnges is that the proposed freight transfer stations located above the Chelsea Section would increase the difficulties of navigation owing to the necessary diagonal crossing by, presumably, car-floats. We are rapidly approaching, in New York Harbor, the necessity for clearly defined lanes of traffic on the part of the various classes of vessels, such as now exist in other principal harbors of the world. At present is seen the rather absurd spectacle of a ship under sail zigzagging across the waters of New York Harbor and seriously interfering at times with the navigation of our largest vessels.

Such practices will undoubtedly have to be regulated in the near future and among such regulations it will be no hardship to require that carfloats leaving New Jersey terminals shall proceed northward along the New Jersey shore until above and clear of all traffic issuing from the Manhattan side below 23d Street, and thence crossing at right angles to the proposed transfer station. Such a regulation will do much to improve the present conditions in the harbor.

In fact, the extension of the present location for moorings for carfloats under the current method will tend to seriously hamper navigation in the North River, for now carfloats leave the New Jersey shore and strike across indiscriminately for the various freight piers of the respective railroads on the North River, presenting constantly reoccurring obstacles to the north and south traffic in the fairway.

One of the minor arguments in favor of removing the carfloats to some point north of 23d Street is that under the above regulation it would leave the lower river, at least on the west side, comparatively free for the navigation of incoming and outgoing steamers.

It seems to me that Mr. DesAnges in further advancing the argument as to the inconvenience that would arise from the handling of freight by moving the transfer points for railroad cars notrh of 23d Street, presents in reality a very strong argument for the adoption of Commissioner Tomkins' plan.

To move the transatlantic and other steamers notrh of 23d Street would mean that an enormous quantity of package and other freight brought into Manhattan for distribution to wholesale and distributing houses downtown would be subject to a long truckhaul or else this distributing center for such freight would have to be moved uptown. Whereas, on the other hand, if carfloats are required to land their cars above 23d Street, this will not mean that the transfer of freight between the car and the shipper must there take place. On the contrary, it will take place

along the elevated railroad in the present downtown shipping and distributing districts. The steamship companies taking up the piers, now occupied by the railroad companies downtown, will be comparatively near this great district, as against a long haul from the proposed uptown location.

Thus, by any other plan than that presented by Commissioner Tomkins, it would be necessary immediately to practically reorganize not only the water front but also the shipping and distributing districts of Manhattan.

THE PRESIDENT:—I am quite sure I express your sentiments when I say to Mr. Barney that we are greatly obliged to him for his most interesting paper and his remarks in the discussion.

The next paper in order is by Naval Constructor Taylor, entitled, "Some Model Basin Investigations of the Influence of Form of Ships upon their Resistance." Mr. Taylor has been called to Europe to testify in a law case, and as the paper is purely a technical paper, I suggest it be read by title.

SOME MODEL BASIN INVESTIGATIONS OF THE INFLUENCE OF FORM OF SHIPS UPON THEIR RESISTANCE.

By Naval Constructor D. W. Taylor, U. S. N., Vice-President.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

It is impracticable to fully investigate the influences of the form of ships upon their resistance, even when we restrict the expression "form" to the shape of a ship apart from dimensions and proportions.

If there were a definite number of possible forms we might cover them all experimentally in time, but the field is infinite in every direction. Thus for a vessel of given dimensions and displacement we might have an infinite number of shapes of midship section, for the fore-body, an infinite number of shapes of the water-line and of the curves of sectional area, and similarly for the after-body.

The case, however, is not quite hopeless as regards results of practical value. If, for instance, the shape of the midship section had no influence upon resistance we need not explore that field at all.

In a paper three years ago before the Society upon the influence of the shape of the midship section upon resistance I showed that within the range of a limited number of experiments the influence of the shape of the midship section upon resistance, while appreciable, was not great, and for the variations practicable in a given case would usually be almost negligible.

The present paper gives the results of some experimental investigations of the effect of shape toward the extremities. The field is a very broad one and the experiments are far from completion. The results now given, however, are complete in themselves and it is believed throw a light on the portion of the field they cover.

Table I gives coefficients, etc., for two series of models, namely, Series Nos. 29 and 32. The displacement in fresh water was in every case 2,250 pounds and the length of each model 20 feet. The midship section coefficient was in each case 0.96 and the ratio of beam to draught 2.5. The longitudinal coefficient of Series No. 29 was 0.60 and Series No. 32, 0.64. Hence, the beam and draught in Series No. 32 were slightly less than in Series No. 29.

It will be observed that each series consists of 16 models. This resulted from the fact that in each case four different curves of sectional area were

used and four different water-lines. The water-lines were largely the same for the two series. Each curve of sectional area being combined with each water-line resulted in 16 models. In addition the models of each series, which all had the same midship section, were made in halves so that each bow could be combined with each stern resulting in 256 possible combinations for each series.

As will be explained later there were a number of different combinations made during the experiments, but not 256. Fig. 1, Plate 2, shows the separate curves of sectional area and water-lines used for Series No. 29 and Fig. 2, Plate 3, shows the same for Series No. 32. Figs. 3, 4, and 5, Plates 4 and 5, show body plans and bow and stern profiles for selected models from Series No. 29, and Figs. 6, 7 and 8, Plates 5 and 6, show the same for three selected models from Series No. 32. The selected models for each series, shown in Figs. 3 to 8, Plates 4 to 6, give the extreme types of each series and a medium type. The actual curves of sectional area and the water-lines used as shown in Figs. 2 and 3, Plates 3 and 4, were calculated mathematically in each case. For present purposes it is sufficient to characterize them by the value of t in Table I; t being what we call the unit tangent at the extremity of the line. That is to say, for water-line curves, for instance, if $t=0$ the water-line is tangent to the center line at the extremity, and if $t=1$ the tangent at the extremity cuts the perpendicular at the center at a point one-half the beam out from the center line; if $t=2$ it cuts the perpendicular at twice the half beam out, etc.

For convenience and simplicity the stern profiles, as will be seen, are rectangular. The bow profiles are practically rectangular. The curves of sectional area have a value at the bow or, in other words, the bow below water is of a simple bulbous form, as indicated. In each case half of the displacement was forward of the center and half of the displacement abaft of the center, the water-line, however, had a greater area abaft the center; the coefficient of the after half of the water-line of Series No. 29 being always five points greater than that of the forward half of the water-line. In each case of Series No. 32 the after water-line coefficient was ten points larger than the forward water-line coefficient. This was done to make the water-lines approach more closely average practice.

The resistance being due partly to the surface and partly to the disturbance created, the first question to be investigated is the relative surfaces of the various models.

Figs. 9 and 10, Plate 7, show relative surfaces as affected by the shapes of sectional area and water-line coefficients. Contours for each sectional area curve are plotted upon water-line coefficient, the coefficient used being

the average coefficient of bow and stern or the coefficient for the whole water-line. It is seen that the variation of wetted surface is not great. It is, in fact, materially less for practical cases than might be supposed from the first glance at Figs. 9 and 10, Plate 7. This for the reason that Figs. 9 and 10, Plate 7, extend to coefficients of water-line plane, etc., beyond those that would be adapted in practice.

Thus, considering Fig. 9, Plate 7, we would not expect to find in practice a vessel whose water-line coefficient was less than its longitudinal coefficient so that the larger wetted surface coefficients in Fig. 9, Plate 7, to the left of the water-line coefficient 0.6 are beyond practicable regions.

Bearing this in mind we may safely say from Figs. 9 and 10, Plate 7, that the effect of practicable variations of shape of sectional area curves and water-line fineness upon wetted surface are comparatively small. Fine ended curves of sectional area result in somewhat greater wetted surface, but the difference indicated in Figs. 9 and 10, Plate 7, is not more than 2 per cent. or so for the very great variations of sectional area indicated in Figs. 2 and 3, Plates 3 and 4.

Let us take up now the experimental results. Fig. 11, Plate 8, shows typical curves of total resistance for the three models from Series No. 29, whose body plans are given in Figs. 3, 4 and 5, Plates 4 and 5, and the three models from Series No. 32, whose body plans are given in Figs. 6, 7 and 8, Plates 5 and 6.

Bearing in mind that comparatively few vessels are driven at speeds greatly above that corresponding to 4 knots for the 20-foot model, it is seen from Fig. 11, Plate 8, that the variation of resistance corresponding to very radical variations of form of the three models in each case are after all not great.

It is interesting to note the critical speed, a little above 4 knots, at which the models change place materially. Models Nos. 1092 and 1191, which are of the extreme type, combining full ended sectional areas and fine ended water-lines are the worst below 4 knots, while between 4 and 5 knots they show themselves the best. This is a typical result and shows that the features of a model should be adapted to suit the speed.

Taking up now the question of residuary resistance rather than the total resistance, Figs. 12, 13, 14 and 15, Plate 9, show the residuary resistance in pounds per ton plotted on speed length ratio for a number of models of Series No. 29, grouped by curves of sectional area.

Figs. 16, 17, 18 and 19, Plate 10, show the same curves grouped by water-lines. Figs. 20 to 27, Plates 11 and 12, give similar information for Series No. 32. It will be observed that considering Figs. 12 to 15, Plate 9,

for instance, two of the curves in each case refer to the straight series and two to models obtained by interchanging bows and sterns. There is in each figure a curve for a model having the finest ended water-line and one for the model having the fullest ended water-line. There is then one curve where the finest ended water-line forward is used with the fullest ended water-line aft and finally a curve where the fullest ended water-line forward is used with the finest ended water-line aft. In Figs. 12 to 15, Plate 9, the sectional area curve for each figure is the same. Similarly, in Figs. 16 to 19, Plate 10, each figure refers to a common water-line, the sectional areas differing. Figs. 20 to 27, Plates 11 and 12, give much the same information as regards Series No. 32 as Figs. 12 to 19, Plates 9 and 10, for Series No. 29, being similarly grouped.

A study of all these figures will show the tendency to straighten out or change relative positions beginning roughly at or a little below the speed length ratio of 0.9, corresponding closely to a 4-knot speed for a 20-foot model.

Considering Figs. 12 to 15, Plate 9, in every case the fine bow appears to be the best at low speeds. Moreover, the fine bow in combination with the full stern appears better than the fine bow in combination with the fine stern. At higher speeds the fine bow with the full stern loses its superiority.

Considering Figs. 20 to 23, Plate 11, while the fine bow appears to be a little the best at low speeds, it does not show as much superiority as it does for the Series No. 29, and at the higher speeds too the fine bow is relatively worse.

Considering Figs. 16 to 19 and 24 to 27, Plates 10 and 12, we see that, broadly speaking, the fine ended curves of sectional area have the better of it at and below a speed length ratio of about 0.9, while at the high speeds they are the worst in every case.

It was diffcult to separate the effect of the bow from the stern. Undoubtedly the resistance of a given stern will be different as it is combined with varying bows, and vice versa.

It was not practicable to test all bows with all sterns, as this would involve testing 256 models for each series. Some investigation was made, however, of the stern effect by combining a single bow with all 16 sterns in each case.

The common bow used was that of Model No. 1201 where No. 3 water-line—a rather full line—was combined with Sectional Area Curve *b*, a rather fine ended type. The curves of residuary resistance deduced from trials with the 16 sterns are shown in Figs. 28 to 31, Plate 13.

Thus grouped by water-lines they show remarkably small variation for all speeds, indicating that we may materially vary shape of curves of sectional area aft without material effect upon resistance.

Figs. 32 to 35, Plate 14, show the same curves as above grouped by curves of sectional area. For moderate speeds these again show comparatively small variations, but at high speeds the variations while not great are appreciable and the results unwelcome. W. Froude many years ago laid down the dictum that broadly speaking the U bow and V stern were favorable to speed. Now the fuller the water-line aft and the finer ended the curve of sectional area the more the stern approaches the V type. Figs. 28 to 35, Plates 13 and 14, indicate clearly that for usual speeds the V type of stern is superior, but scanning Figs. 32 to 35, Plate 14, we find at about a speed length coefficient of 0.95 a change in relative positions of the curves and in every case the fine water-line aft is the best at high speeds.

Careful consideration of the figures will, it is believed, warrant the conclusion that the primary factor involved here is water-line fineness, the variations with changes in curves of sectional area being subsidiary. There is not much to choose between the sterns with fine ended and full ended curves of sectional area. Of course in practice we would wish to use with a fine water-line aft a fine ended curve of sectional area to avoid a bulbous stern.

There remain two questions to be considered; namely, what is the best combination of coefficients in the case of each series and how much can we affect the resistance by adopting this best combination. Figs. 36 to 41, Plates 15 to 20, show contours of residuary resistance in pounds per ton for Series No. 29 of longitudinal coefficient 0.60 plotted upon the values of t for the sectional area curves and the values of bow water-line coefficient. These refer to the 16 models indicated in Table I and not to interchanged bows and sterns.

Figs. 42 to 47, Plates 21 to 26, give similar contours for Series No. 32, of longitudinal coefficient 0.64.

The residuary resistances are so small for low speeds, below $\frac{V}{\sqrt{L}} = 0.7$ that it is hardly feasible to determine reliable contours from them and indeed at the higher speeds the residuary resistances do not differ sufficiently to allow reliable contours to be drawn without cross fairing out unsystematic differences. For Figs. 36 to 41, Plates 15 to 20, from Series No. 29, we see that at and below a speed length ratio of 0.9 there appears to be a distinct region for minimum residuary resistance, corresponding to quite fine ends on the curves of sectional area and to a bow water-line coefficient slightly greater than the longitudinal coefficient. Bearing in mind that for Figs. 36 to 41, Plates 15 to 20, fine water-lines forward are associated with fine water-lines aft we conclude from Figs. 32 to 35, Plate 14, that the minimum results

of Figs. 36 to 41, Plates 15 to 20, could be slightly improved by using full after water-lines—the V stern.

In the case of Series No. 32, the region of minimum residuary resistance for low speeds is not so well defined and appears to correspond to a smaller bow water-line coefficient than in the case of Series No. 29. It should be remembered, however, that in Series No. 32, the stern water-line coefficient is ten points greater than the bow coefficient; while in Series No. 29 it is but five points greater. In each case, as we pass beyond the region of critical speed length ratio, say from 0.85 to 0.9 there is a marked change in the contours. For $\frac{V}{\sqrt{L}} = 1.1$ for instance, the minimum residuary resistance corresponds to the fullest ended curves of sectional areas while the corresponding bow water-line coefficient falls off materially.

In other words, for the minimum resistance at the high speeds we need to materially fine the ship at the water-line and fill it out below water. The broad conclusion to be drawn from the results I have laid before you are confirmed by other experiments which agree in indicating that the type of form suitable for low and moderate speed length ratio below 0.9 is not at all adapted for high speed length ratios of 1 and above.

The reason is I think to be sought in the relative dimensions of the ships and the waves which it makes. At the low speeds only the ends of the ship and more particularly the forward end materially affect the resulting waves, which, after all, are small and offer but comparatively small resistance. At the high speeds, however, the whole fore-body has to do with the creation of the waves, and we decrease resistance by making the water-line as fine as possible and putting as much as possible of the displacement well below water where the pressures due to its thrusting itself into the undisturbed water will be as much as possible absorbed in doing the necessary pumping aft of the water and not in raising the surface into waves.

Let us attempt now to gain some idea as to the quantitative effects in actual cases of the variation of form we have been considering. Consider the moderate speeds first. Say Figs. 37 and 42, Plates 16 and 21, where the speed length coefficient is 0.8.

In Fig. 37, Plate 16, the minimum residuary resistance indicated in pounds per ton is 1.4 and while the possible variations in water-line curves of sectional area are somewhat a matter of opinion it seems reasonable to say that without a guide we might adopt coefficients and curves which would give us a residuary resistance as high as 1.8 pounds per ton.

The possible gain then would be about 0.4 of a pound per ton which is

a large percentage of the residuary resistance, but the resistance due to wetted surface would vary but slightly and would be for the usual run of the ships somewhere in the neighborhood of 5.2 pounds per ton, making the total resistance per ton for a speed length coefficient of 0.8 in the neighborhood of 7 pounds. We have then a possible gain of 0.4 pounds in 7 pounds, or nearly 6 per cent., but bearing in mind that the fine ended features which helped us as regards residuary resistance would slightly increase the wetted surface we may say that by adopting the best combination of water-line and sectional area curves we may perhaps gain 5 per cent. over the worst likely combination. The conclusions to be drawn from Fig. 42 for the same speed and the longitudinal coefficient of 0.64 are practically the same, the possible gain being, if anything, somewhat greater.

Consider now Figs. 41 and 47, Plates 20 and 26, for the speed length coefficient of 1.1. In Fig. 47, Plate 26, the practicable variation in residuary resistance is roughly two pounds, the difference between 8 and 10 pounds, or some 25 per cent. At this speed the average frictional resistance in pounds per ton for vessels of the type of the models of Series No. 29 would be also about 10 pounds to the ton so the gain indicated would be of the order of 10 per cent.

From Fig. 47, Plate 26, for the longitudinal coefficient of 0.64 we would draw the same conclusion, but it should be pointed out that in practice we would seldom, or never, force a vessel with a displacement length coefficient of 129, as shown for Series Nos. 29 and 32, in Table I, up to a speed for which the speed length coefficient is 1.1. We would adopt different proportions and dimensions so that the residuary resistance would assume relatively less importance. For the high speed case also then we would hardly be warranted in saying that the possible gain in passing from the worst likely combinations of water-line and sectional area curves to the best would be more than some 5 per cent.

It will be found upon studying the contours and lines that while for medium speed work lines of the type of Figs. 4 and 7, Plates 4 and 6, are excellent, there is material decrease in resistance for high speeds by approaching the type of Figs. 3 and 6, Plates 4 and 5, or the bulbous bow.

It is true that Figs. 3 and 6, Plates 4 and 5, indicate also a bulbous stern but we have found that the main factor here is the fine water-line aft for high speed and not the full ended curve of sectional areas.

As pointed out already the models of Series Nos. 29 and 32 are not of high speed type and I would not feel warranted in drawing any conclusions from them as to high speed work did not results so far from high speed models appear to agree with those from Series Nos. 29 and 32. I think, then, there

is little doubt that for high speed work up in the region where $\frac{V}{\sqrt{L}}$ is from 1 to 1.2 the bulbous type of bow is distinctly superior as regards resistance.

While there are some practical objections to it, they do not seem to me very serious and I see no reason why in many cases some approach to the bulbous type could not be made to advantage.

The extreme U type of bow where the fore foot is carried as far forward as possible and the sides are practically vertical, the water-line being made as fine as possible, is the nearest approach to the bulbous type of bow that can be made without departing from conventional ideas, and where adopted this type of bow will give less resistance for high speed work than bows of less pronounced U or V type.

I desire in conclusion to record my appreciation of the valuable advice and assistance given me in the preparation of this paper by Mr. L. F. Hewins of the Model Basin staff.

THE PRESIDENT:—We will pass to the next paper on the programme, and will ask Professor Sadler if he will give way to the presentation of the paper by Mr. Nixon? Professor Sadler consents, and we will take up the paper entitled, "Panama Canal and American Commerce," by Lewis Nixon, Member of Council.

Mr. Nixon presented the paper.

PANAMA CANAL AND AMERICAN COMMERCE.

By Lewis Nixon, Member of Council.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

That Commerce will be stimulated by the opening of the Panama Canal is generally admitted, but that its advantage will be uniform to all countries is of course impossible.

This is because some nations are keenly alive to the desirability of conserving the material interests of their people, leaving to other countries the task of looking out for their own.

So it will follow as it always has in the past that in the readjustment of commercial conditions, to be brought about by the opening of our canal, the nations who jealously safeguard their interests and utilize to the utmost possibilities confronting them will profit more largely than those who are indifferent.

The men who framed our Constitution and who in Congress later carried out its intentions and ideals in laws, thoroughly understood that the three pillars of national greatness and prosperity were commerce, agriculture and manufacturing.

Patriotism and not political expediency was the moving spirit and a handful of men, in debt, without resources or credit, with the fear of no country in their minds and with an eye singly to the progress of the United States of America enacted legislation that quickly gave us wealth, power and population.

We all know that departure from the wise policy of our forefathers was coincident with the beginning of the decline of our merchant marine, while other nations have become strong and rich through utilizing the opportunities we have thrown away.

We are always told that we had to develop our internal resources. That is true, but had we adhered to our original, constitutional maritime policy we should have saved the money necessary for such development instead of turning over vast profits to others to be reinvested here and make a vast drain forever upon our earnings.

It is said by those always eager to find excuses for continuing our dependence upon the oceans that our Foreign Trade is mounting now to

vast proportions. To students of the Strategy of Trade it is apparent that had we our own plant, and world-wide trade connections we once had, that our foreign trade would be far greater than it is now. The doctrine of being satisfied with half a loaf when you can get loaves should not appeal to progressive Americans.

The doctrine of live and let live is altruistic but when a nation ceases to progress or grow it dies.

A boy may be strong and powerful as a youth but once grown to mature manhood and strength a shrinking back to youthful stature would indeed be pitiful.

We neglect the commercial pillar although the proportion of exports which consists of foodstuffs and staples that foreign countries must have to feed their people and their factories is falling, while the proportion of manufactured commodities in which we have to meet the competition of the world is increasing.

Reliance upon the sophistry that the reason others carry our goods is that they can do it cheaper than we can, means the gradual coming of hopeless and entire dependence upon others to do our work. Charges are always all the service will bear.

A country without the will or capacity to look out for its own interests will soon have no interests worth looking after.

I need not point out here how large a factor ocean transportation is in the sum total of national prosperity, nor do I wish to discuss here the means for a revival of our merchant marine to a tonnage in the foreign trade adequate to our needs.

What this Society probably wants to know is, Are there means by which the vast sum spent for the Panama Canal can be of help to the varied interests of this country instead of furnishing issues of bonds with which to aid the continuance of our present currency system, the existence of which is as much a tax upon us as is the non-existence of a merchant marine?

Several of the European nations rebate the toll charges of the Suez Canal to the vessels flying their respective flags.

But they did not build the Suez Canal even though they may have shares in it. But we built the Panama Canal with our own money through our own territory.

The great bug-a-boo of the present day that is dangled before the American public is that a treaty forbids whenever something must be done to protect our interests.

Why a self-respecting country could ever sign the Webster-Ashburton treaty I am at a loss to understand but though supplanted in its provisions

by the Hay-Pauncefote treaty many were willing to harken back to the older treaty to our own undoing when it was proposed to protect our own by fortifications.

Of course our vessels passing through our own waterway should pass through free. But again a treaty forbids.

What is our manifest duty as an independent nation with the sovereign right to do as it will with its own. To give notice that in this respect the treaty does not bind us, and if this is questioned abrogate the treaty.

Now listen to the inspired chorus railing of breach of faith.

Bargains of this sort match privilege against privilege and it is not expected nor is it equitable that they should be one-sided. In this instance we are bound not to prefer our own ships, an enormous advantage given to our competitors. We are given permission to build the canal—a permission we should as a nation be ashamed to admit necessary.

A rebate to our own vessels would be a cowardly compromise. This canal is a thoroughfare through our territory and should be free to our vessels.

Our treaty makers up to the last few years have unhesitatingly swapped American rights for doubtful considerations which have usually turned out worthless.

Congress seeing this fatal tendency to dicker, after the War of 1812 when we made the much-to-be-regretted treaty of 1815, stopping our constitutional right to regulate commerce in direct foreign trade, passed a law which at least removed one part of our marine from such hazard.

They passed a law confining the coasting trade to United States vessels. This remnant of the inspired legislation of the patriotic men who enacted our early navigation laws stands to-day—a monument of constructive legislation. Without it we should have lost the demand for coasting vessels that kept alive the flickering flame of shipyard capacity which roused by the proposal that we should buy our first man-of-war in Europe laid the foundation of the splendid shipyards we have to-day.

Our tonnage in the coasting trade is enormous but must not be confused with our tonnage in the foreign trade which in 1911 is less than it was in 1811.

To one man of this country, more than all others, who fought for years for the recognition of the American shipbuilder, Charles H. Cramp, do we owe our present Navy. Beaten at one point and having to permit the building of hulls here, American doubting Thomases begged that we import the machinery and the splendid patriotic stand taken by Secretary Whitney, when he declared hull and machinery should be built in the United States if built at all, was based to my knowledge upon his faith in the promises of

Mr. Cramp. This with no disparagement of the splendid work done by John Roach, Taylor Gause and others, but Charles H. Cramp made the fight and won.

He could not have done so had it not been for the coasting trade law, for his great abilities would have been forced into other channels.

We still have this law left after the betrayal of the obligations of Congress to regulate commerce in American interest by the repeal of the earlier laws that did so.

Can we use this last prop by any extension of it to our advantage and to still further stimulate shipowning and shipbuilding?

Happily we can. Mexico, Central America, the West Indies, and the northern shores of South America are at the door of the Panama Canal. As trade and transportation focus to the Isthmus and the Governments surrounding it become stable and safe fields for investment so that their vast potential resources may contribute to the world's commerce, I look to see in a few years the Caribbean Sea and the Gulf of Mexico girdled by prosperous cities with trade rivaling in activity and prosperity the cities of the Great Lake basin. By treaties with these countries we should extend our coasting laws to them with the understanding that all vessels owned and operating under the flags of either party to the treaty, say on January 1, 1912, shall enjoy reciprocal liberty of commerce in the ports of either party, after that date vessels constructed in either country to have the same privilege.

Such an agreement with Mexico and Cuba alone would fill to overflowing every shipyard now in the United States.

The splendid work of the State Department under Secretary Knox in providing stability and credit in countries whose staggering debts have kept such nations in revolution and under fear of intervention has prepared the way for such a policy.

Is there any objection? Of course! Treaty experts have cunningly foreseen such possibilities and have got us to bind ourselves not to give ourselves anything, even of our own, unless they too are favored.

Are such treaties absolutely essential to doing business?

Of course not, our commerce was most flourishing before the greater part of our commercial agreements were made.

What is the hindrance to legislation in our own interest?

American public opinion manufactured in Europe.

I cannot end this paper without saying that my earnest conviction is that we must return to our early policy of discriminating duties and tonnage taxes if we are to revive our merchant marine in the foreign trade, and that

I am sorry that I cannot see the advantages, as conditions now exist, of the Panama Canal other than as a war measure and as an altruistic enterprise in which charity begins abroad. Commodities leaving our borders are not marketed by us, are not carried by us, are not underwritten by us and are not financed by us. The cream of commerce goes to others who do these things for us.

There has been much said about the establishment of mail lines to South American ports. Such lines, have, unlike a subsidy policy, constitutional warrant and their establishment is clearly within the power of Congress.

In the establishment of such there are two points needing attention. We must not gauge our service by comparison with existing ships running from the United States to South America, but by comparison with ships running from European ports.

The proper doctrine is as follows:

That vessels running from the ports of the United States to the ports of other American States, should be at least equal in comfort and convenience to those from any port in Europe, and of such speed, that duration of voyage under analogous conditions, shall be less from the ports of the United States than from the great commercial ports of Europe.

Another vital point is that good business calls for foresight in renewals. It is foolish to spend our money for a fleeting service and when we see newer and better ships constantly added to foreign lines, we should realize that we must do the same in the way of keeping up a competitive service. So contracts should not be for short terms. As the necessity for new ships arises owners should not find themselves with a few years to run at the end of which they may have ships on their hands with no place to use them. Personally I think thirty years the absolute minimum for such contracts. In this way, as needed, new and better vessels will be added and the older vessels will go into the freight or the accommodation and reserve service so essential to a growing line.

DISCUSSION.

THE PRESIDENT:—Gentlemen, this paper by Mr. Nixon is before you, and we will be glad to hear any one in discussion of it. Mr. Cox, the Secretary, has received a typewritten discussion from Mr. Chamberlain, Commissioner of Navigation.

MR. EUGENE T. CHAMBERLAIN, *Honorary Associate* (Communicated):—Ten years ago before a noteworthy international assemblage, Mr. Clement A. Griscom, for many years President of The Society of Naval Architects and Marine Engineers, spoke these words:—

"The United States proposes soon to begin, at its own expense, the great work which remains to be done for the expansion of the world's shipping and commerce, the construction of a canal across the isthmus separating the Atlantic from the Pacific. Whatever route may be chosen, whatever preliminary negotiations may be necessary, I am confident American sentiment will sustain me in asserting that the canal shall be open on equal terms to the shipping of all nations; that no special commercial privileges in return for our investment will be sought for the United States; and, in accordance with our national policy the charges on shipping using the canal will be no more than are necessary for its official administration. The canal is to be the first contribution of the United States to the new American development of this century."

The occasion was the banquet, presided over by Lord Brassey, first Honorary Associate of the American Society of Naval Architects and Marine Engineers, and tendered at London on June 5, 1901, by the London Chamber of Commerce to the New York Chamber of Commerce to commemorate the successful efforts of both organizations toward an honorable solution of threatening difficulties arising between the United States and Great Britain over Venezuela. Negotiations between the United States and Great Britain for the abrogation of the Clayton-Bulwer treaty were under way; but the Hay-Pauncefote treaty, whose principle Mr. Griscom forestalled, was not concluded until November 18, 1901. That principle is as old as Burgoyne's surrender and our recognition by nations, and found its first expression in our first treaty, the treaty of amity and commerce concluded with France on February 6, 1778. Since that time it has been the unswerving rule of American diplomacy.

The Clayton-Bulwer treaty of 1850 bound the United States—and equally Great Britain—to these obligations:—

1. To maintain no exclusive control over an Isthmian Canal.
2. To erect no fortification around it.
3. To use no influence with the country through which the Canal might pass to acquire exclusive canal navigation privileges for our citizens.
4. To join with Great Britain in protecting the Canal and guaranteeing its neutrality.
5. To join with Great Britain in fixing tolls and regulations.
6. To regard the Canal as "for the benefit of mankind on equal terms to all."

The motives or wisdom of the framers of that treaty sixty years ago no longer concern us. It became necessary to abandon the treaty or the Canal. A new treaty, suitable to changed times and conditions, was concluded on November 18, 1901, between the United States and Great Britain.

The Hay-Pauncefote treaty gave the United States the exclusive right to build, regulate and manage the Canal; it abrogated the prohibition against fortification, and while preserving the neutrality of the Canal it abrogated the joint protectorate. It provided, in short, for an American canal, with neutrality guaranteed, subject only to the principle which in substance every American Administration has always incorporated in all its treaties with foreign nations for the regulation of trade between us and them. That principle was thus expressed in the first section of Article III of the Hay-Pauncefote treaty:—

"1. The Canal shall be free and open to the vessels of commerce and of war of all nations observing these rules, on terms of entire equality, so that there shall be no discrimination against any such nation, or its citizens or subjects, in respect of the conditions or charges of traffic, or otherwise. Such conditions and charges of traffic shall be just and equitable."

If this Article shall prove to be a serious obstacle to American commercial navigation through the Panama Canal, if the Canal shall fail to enhance the maritime importance of the United States upon both oceans, and to stimulate the industries, which assemble through their representatives at the meetings of the Society of Naval Architects and Marine Engineers, then the Canal will fail in purposes which many of our people believe to be of equal importance with the usefulness of the Canal for national defense. If the Article shall prove to be the undoing of the art of shipbuilding in this country even for a decade, the gravest national mistake has been made. Such a mistake was not made.

The Article of the Hay-Pauncefote treaty corresponds generally with the provisions in the Convention of Constantinople, signed October 28, 1888, for the free navigation of the Suez Canal. The Suez Canal was built by a joint stock company, of which the British Government is the largest stockholder, and is operated primarily for the profit of the stockholders. In 1910 it paid them an annual dividend of 30 per cent. after meeting all charges and providing ample reserve funds. It cost up to December 31, 1910, 656,178,271 francs. The Panama Canal is being constructed by the people of the United States at a cost up to the probable date of opening of $375,000,000. It is not built as a source of cash dividends to the United States and is never expected to become such.

Although the Canal is the property of the American people in the same sense in which the improved harbor of New York, the Mississippi and its jetties, and the "Soo" Canal are their property, it has been acquired differently and in some particulars must be differently administered. We had to acquire the right of way for the Canal from the Republic of Panama, and in return for the concession we agreed—to name only some of the conditions:—

(*a*) To pay Panama $10,000,000 in gold coin on the date of the treaty's ratification, February 26, 1904;

(*b*) To pay Panama $250,000 annually, beginning February 26, 1913; and

(*c*) In Article XVIII:—

"The Canal, when constructed, and the entrance thereto shall be neutral in perpetuity, and shall be opened upon the terms provided for by Section I of Article III thereof, and in conformity with all the stipulations of the treaty entered into by the Governments of the United States and Great Britain on November 18, 1901."

Section 1 of Article III of the Hay-Pauncefote treaty has already been quoted.

The international obligations assumed suggest the administration of the Panama Canal as a politico-financial entity or corporation, distinct from the general finances of the Treasury Department. To demonstrate to all nations that the charges are just and equitable the balance sheet should always be open to inspection, showing the daily expenses of the Canal, including an interest charge of about $30,000 a day. To show that there has been no discrimination against any nation, that balance sheet should show the tolls paid in respect of every "vessel of war," be it American, British or German, and the tolls paid in respect of every "vessel of commerce," be it American, Italian or Swedish. There must be a payment in respect of every vessel "of commerce and war" at amounts fixed, and on bases fixed (displacement, register tonnage, or whatever be chosen) which shall not vary according to the flag the ship floats. The alternative is no tolls whatever. Thus far we are bound by treaties and no further.

We might perhaps as proprietors have proposed for American battleships the privilege of passing through the Canal free of tolls. We did not do so, although part of the price we paid to Panama was the concession—for what it is worth—of transporting her troop-ships over the Canal "at all times without paying charges of any kind." Payment apparently will be made for vessels of war and for vessels of commerce, but so long as there is no discrimination according to the flag the rates may vary. We may provide that all battleships shall pay fifty cents per displacement ton and all merchant ships shall pay $1.20 per register ton.

The principle which underlies the treaty is that of contribution toward the maintenance of the Canal in proportion to use and without national favor. Under any other principle we should be at liberty, if it suited the preferences or prejudices of those at any time temporarily charged with the administration of canal finances, to require that payments for Russian ships, for illustration only, should be double or half the rates paid for French ships, or that payments for foreign ships should constitute the entire receipts and that nothing should be paid for American ships. So long as payment is made the treaties do not and cannot undertake to declare by whom they shal be paid. In respect of vessels of war, the payment of tolls, of course, will be direct from the Treasury of the nation whose flag they fly, respectively. In respect of vessels of commerce, the payment will be a matter of domestic policy to be determined by each nation for itself in accord with the views which it entertains of the usefulness of its merchant shipping and the importance and purposes of navigation under its own flag through the Canal. Some nations will doubtless require their shipowners to pay the Panama Canal tolls on their own vessels and to make good the tolls with other operating expenses out of freight

charges. Such is the present practice of Norway in respect of Suez Canal tolls. Some nations will appropriate money directly for the payment of the Panama Canal tolls of vessels under their flags respectively as Russia and Austria have paid the Suez Canal tolls of some of their ships. Other nations will vote subsidies to national mail steamships, adequate to pay their Panama Canal tolls, as Spain has already done in anticipation of a Spanish line to Valparaiso, and as Great Britain, Germany and Japan have done for years in behalf of contract mail steamships passing through the Suez Canal. The right to spend our own money as we wish will not be disputed and if the Congress of the United States shall see fit to declare it the policy of the country to pay directly from the Treasury the Panama Canal tolls of American vessels of commerce as well as of American vessels of war, indisputably it can do so consistently with scrupulous regard for all of our international obligations. Whether it be judicious to tax the whole people for American navigation of the Canal rather than to tax American vessels and thus indirectly the cotton, corn, lumber, fruits and manufactured products which we send through the Canal, is a question to be determined in the halls of Congress and not before international tribunals.

That proposition is the basic principle of the last great public measure, introduced by one whose public services in behalf of American navigation have for years commanded the respect of the Society of Naval Architects and Marine Engineers, the late William P. Frye, Senator from Maine and long President *pro tempore* of the Senate. The Frye Bill provides:—

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That all tolls and transit charges which may hereafter be imposed on public vessels of the United States and on merchant vessels of the United States for passing through the Panama Canal shall be paid from any money in the Treasury not otherwise appropriated, and there are hereby appropriated annually, out of any money in the Treasury not otherwise appropriated, such sums as may be necessary for the purpose; and such appropriations shall be deemed permanent annual appropriations."

Though novel perhaps in form, the bill in principle has been the unchallenged policy of the United States for a quarter of a century. Since July 1, 1884, Congress has voted $527,065,707 for the construction and maintenance of river and harbor improvements. These great expenditures have made possible the building in Great Britain of the commercial masterpieces of naval architecture, whose distinguished designer is to be honored by the American engineering societies at the coming meeting. To those appropriations the builders of the Great Lakes have been indebted for the chance to develop the most efficient type of the cargo-boat to be found on any water. Those hundreds of millions have contributed by reducing the cost of transportation to develop our domestic commerce and in foreign trade to lower in effect the tariffs of nations. It would have been well within the

powers of Congress to have prescribed that vessels, American and foreign, making use of these improved waterways costing half a billion dollars should pay charges at least sufficient to maintain the improvements, if not to pay the annual interest of $10,000,000 on government bonds, kept outstanding and not redeemed. Such charges could have been levied, subject to the condition that there should be no discrimination based on flag, incorporated in our treaties, of which Article III of of our treaty with the Netherlands may serve as illustration:—

"Neither party shall impose upon the vessels of the other, whether carrying cargoes or arriving in ballast from either of the two countries, or any other country, any duties of tonnage, harbor dues, light-house, salvage, pilotage, quarantine, or port charges of any kind or denomination, which shall not be imposed in like cases on national vessels."

In fact the policy of the country was declared in Section 4 of the River and Harbor Act of July 5, 1884:—

"No tolls or operating charges whatever shall be levied upon or collected from any vessel, dredge, or other water craft for passing through any lock, canal, canalized river, or other work for the use and benefit of navigation, now belonging to the United States or that may be hereafter acquired or constructed."

We do not charge ships, American or foreign, of war or of commerce, for their use of the improved harbor of New York, the Mississippi and its jetties and the "Soo" Canal. If the Hay-Pauncefote treaty of 1901 be deemed a concession of timidity in guaranteeing equality of Canal tolls, then the Forty-eighth Congress, presided over by the Hon. George F. Edmunds, of Vermont, and the Hon. John G. Carlisle, of Kentucky, made absolute surrender in declaring that no tolls whatever should be levied upon any vessel, foreign or American, for passing through any work for the benefit of navigation belonging to the United States. The obvious truth is that the clear-sighted statesmen who from Washington to Taft have directed the policy of the United States have found equally sagacious statesmen abroad and in so shaping the commercial policies of nations as to give the largest opportunity for ocean navigation they have been the greatest benefactors of naval architecture.

Why charge any Panama Canal tolls? The Panama Canal differs from all other American public works for the benefit of navigation in one important particular. Every river and harbor improvement—with very few and inconsiderable exceptions—has an American terminal, and the people of the United States in some form derive benefit from every vessel making use of the improved waterway. The ships may be foreign, but their cargoes or passengers in part at least are American, coming from or going to the soil of the United States. The Panama Canal is in foreign territory over a narrow strip of which the United States has acquired jurisdiction in perpetuity for a specific purpose. Ships will pass through

that Canal which will never touch the United States and in some instances may even deprive us of trade which would have been ours, had there been no canal. The direct trade between Europe and the west coast of South America through the Canal means nothing gained and perhaps something lost commercially to the people of the United States. As an incident to the development of our means of domestic transportation between the Atlantic and Pacific coasts and to doubling our Navy, we are giving to foreign nations an exceptional opportunity for the transit of their warships and the development of their own trade with one another. This trade, foreign to us in every respect, could not expect and doubtless never entertained the notion that it should not make reasonable recognition in the only form possible of the opportunities opened to it by the United States.

It may be contended that the coastwise trade of the United States from our Atlantic to Pacific ports should be exempt from tolls. The coastwise trade is confined to American vessels, and we may find it difficult to carry conviction with the argument that such an exemption would be anything else than a discrimination based on the flag. Our treaties usually carry an article exempting the coasting trade from their provisions. Thus Article XIII of our treaty of 1911 with Japan provides:—

"Article XIII. The coasting trade of the High Contracting Parties is excepted from the provisions of the present Treaty and shall be regulated according to the laws of the United States and Japan, respectively."

The Panama Canal treaties might perhaps have contained such an exception but the fact remains that they do not, and the exception cannot readily be read into them. If such an exemption could be made now, it would give American shipping in that trade no advantage over the provision made for it in the Frye Bill. The Treasury of the United States is not relieved of the cost of maintaining annually our great system of river and harbor improvements because the navigation is untaxed. The use of the Canal to its fullest capacity, necessary to produce revenue, probably could not be secured, if the cost of operation were assessed, under modified treaties, solely against foreign vessels in the foreign trade of the United States and of other nations. In that event a share of the burden of maintenance would still fall upon the Treasury of the United States. It is immaterial as a tax problem whether money be appropriated directly from the Treasury of the United States to pay the tolls upon American ships and the money thus appropriated be used to maintain the Canal, or whether the money be appropriated directly for Canal maintenance.

Whether American shipbuilding shall take new life from the Panama Canal or whether its very existence shall be threatened will depend upon the policy, to be fixed at the coming session of Congress. If contrary to our general policy commerce between the States shall be taxed in peace and it shall be determined to put directly and alone upon American merchant shipping the entire toll contributions of the

United States in behalf of its war fleet and of the manifold forms of domestic production to be benefited by the Canal, then it is reasonably certain that preparations by American shipbuilders will be tardy and insufficient to meet any considerable demand for coastwise transportation through the Canal. The expectations of the people are set high, and if ample transportation facilities are not ready from the outset, a demand will be inevitable for the repeal of the coastwise laws and the admission of foreign-built ships into trade between our Atlantic and Pacific ports.

MR. NIXON:—Mr. Chamberlain attacks the few ideas that I have advanced, the attack being made on the very lines on which they are usually attacked. He has gone to great length to establish the fact that there are treaties in the way of preferring our own ships and saying to the world that through the Panama Canal our ships will go free just as they would through any other highway of the United States. He makes the contention there, as I discovered by reading his article somewhat hurriedly, that we can treat all nations with equality, and that is twisted to the extent that we must treat all other nations as ourselves.

My interpretation of that, and a fair mercantile interpretation, is that we should not treat any other nation using that Canal with any particular favor, compared with other competing nations, or other nations having canals of their own.

MR. WALTER M. MCFARLAND, *Vice-President:*—I had the pleasure of reading Mr. Nixon's paper, as a member of the Publication Committee, and was very much pleased with it, indeed. As I said here last year (or possibly the year before), he has made such a careful study of this whole subject of advancing the interests of the Merchant Marine that I feel anything he says on the subject is worthy of the most careful consideration.

Generally speaking, I should say that I am in agreement with him as to the method that he follows. It might be that some question of detail would come up on which we would not agree, but in general I think his plan is right, and I believe that this is a tremendously live subject for our Society. I have said that before and I say it again. There is no other organization in the country that has the same vital interest in an increased merchant marine that we have. I feel that everything we can do to push it along ought to be done, and that the interest Mr. Nixon shows by giving us his paper is worthy of a great deal of praise.

MR. JOHN REID, *Member:*—I think, gentlemen, that every story has two sides to it, and I don't want you to imagine for a moment that I am going to say anything that will run counter to any ideas or theories Mr. Nixon has about the improvement of the merchant marine of the United States. The United States must have a merchant marine and have it very quick, if it is to take the position in the world that its size and influence entitles it to, and everything that would help that will be for the advantage of the United States and the world in general, but when you come to talk about abrogating treaties and giving free passage to

United States vessels through the Canal and neglecting treaties which give important rights to European nations, I am not specifying any particular one—we will say Germany or any other foreign nation—you run up against this, that the other fellow has something to say about that, and he does not usually do it by coming to you diplomatically and saying "We have a treaty with you that you were to leave the canal open," but he says, "I have a lot of ships, and want to use that Canal, and I have a lot of goods to buy from you," we will say grain from the West and canned goods and provisions, etc., and everybody knows what a tremendous trade that is. But the world is getting smaller every day, and if you put obstacles in the way of people buying the goods where they get them to the best advantage, they go somewhere else, and that is quite a serious matter for this country. You want to increase your export trade, and have your own ships to enable you to do that, but if you put a high rate on your freight, and put obstacles in the way of other people carrying goods in their own bottoms, they simply get these same articles from another place.

I know a little about this thing, because I have noticed—take the British market by way of reference, the British market has been buying grain in enormous quantities throughout the Canadian Northwest. Until a few years ago the basis of all their flour came from the northwestern part of the United States and Canada. That trade petered out a year or two ago and there was no grain going down the St. Lawrence, and the reason was the Canadians put obstacles in the way of the grain going out. They unduly increased the price of it. There were good crops elsewhere, and the British simply bought their grain in the Argentine, Austria, or wherever there was a surplus. Grain is going to be such a delicate thing to handle that it does not require any diplomatic moves to upset the export trade. The buyer has a lot to say how he shall have his stuff shipped. That is your difficulty. Incidentally, see how much it will mean to the export trade of the United States to have that freedom to employ foreign shipping, because you are going to do your own coasting trade—that you have already determined to do—therefore you can do what you will with the fees from vessels passing through the Canal, but it will require more than the rebate of the dues from the Canal to promote that foreign shipping which you are so anxious to have.

I do not think one should forget either that this idea of giving special privileges or having special tariffs is more or less an exploded idea to-day. It is one in which a great deal of splendid work has been done in developing new interests in this and other countries, but the people to-day are more concerned about the nation pulling as a whole and getting their goods shipped in the cheapest possible way.

While the United States is to have its own merchant marine, with the world closing all around it, so to speak, I see that the tremendous asset in the development of the United States is that it has been able to draw on Norway, Germany and Britain, and every other country, for cheap freight. The export trade of the United States is as much based on that to-day as on any other factor. The margin of profit on whatever price you get for an order in China depends on the rate

of freight, and you cannot increase the rate of freight without losing that business, especially as you pay much higher wages for your labor, and I do not see how you will get any particular advantage by getting a rebate of these Canal dues. This is a personal opinion, and I have only put it out as the other side of the story.

THE PRESIDENT:—Is there any further discussion of the paper? If not, we will ask Mr. Nixon to close the discussion.

MR. NIXON:—In the first place, the last speaker said he did not believe in encouraging enterprise. I want to say that the great enterprise on the oceans is encouraged to the extent of $42,000,000 by our foreign competitors. He says he thinks we might as well give up, since our wages are so high. We will never do anything unless we start somewhere. Here is a chance—we have a Canal, backed by our own people with our own money, and which is constructed through our own territory. There was a veiled insinuation that possibly two can play at the same game. If we go through the Suez Canal we pay. Other nations have been able to get by foresight, shares in the Suez Canal which return to them in profits what they pay for rebates in ships. We are to spend $400,000,000 on the Canal, and we say we will collect tolls, not to make it a profitable enterprise, but as an altruistic enterprise, which must pay its own way. Since the greater part of the ships of the world are under a foreign flag, they will pay the tolls, and if we are to start to develop our merchant marine, we must start somewhere. It is a great problem. Other nations are not going to give it to us easily. There is no brotherly love in connection with the matter. We must go for it and fight for it. Unless we take drastic measures to carry freight in our own bottoms, we will not be able to do it.

To say that we cannot abrogate treaties is to say that treaties are so binding in their general characteristics a nation must always abide by them. In olden times most of our industrial conventions were separated from the idea of a treaty of peace. In a treaty of peace you do not say that you will be at peace for a certain number of years, but forever, unless some cause brings about a war. But in a commercial convention, by which certain nations secure certain advantages, every one of these conventions have a limit of time during which they are operative. When you take into account the commercial character of a convention, it is terminable. Mr. Reid says that we cannot apply discrimination as affecting our foreign trade without violating the leading principle of our treaties, but here is a case wherein we are bound to prefer our own ships, in our own water, in a great enterprise paid for by our own people, and in a territory over which our own flag floats.

If we are to make a declaration of independence in favor of American shipping on the ocean, we must begin sometime, because every day is lessening the opportunities for doing this, and delay will only ultimately prevent our ever rising to the occasion. In other words, hopeless dependence on foreign trade progressively

increases, and while the plan suggested may not do it all, it will be a very good lift, and it is about time to start.

THE PRESIDENT:—Is there any further discussion? I presume a vote of thanks is due to Mr. Nixon for his timely expressions on the subject of the merchant marine..

We will now proceed to the paper entitled "The Resistance of Some Merchant Ship Types in Shallow Water," by Prof. Herbert C. Sadler, Member of Council.

(Vice-President McFarland in the Chair.)

Professor Sadler presented the paper.

THE RESISTANCE OF SOME MERCHANT SHIP TYPES IN SHALLOW WATER.

By Professor Herbert C. Sadler, Member of Council.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

The effect of shallow water upon the resistance of vessels has been the subject of a certain amount of investigation and in a general way the influence of depth of water upon the speed of a vessel is familiar to most members of the profession.

In general, however, the published results refer to vessels of the warship type and more especially to destroyers, scouts and cruisers.

During the past two years, when occasion permitted, a number of models of various merchant ship types have been tested in water of varying depth, in the "Tank" at the University of Michigan; and although it cannot be claimed that the whole field has been covered, the following results may prove of some interest and value.

The characteristics of each form are given with the curves and it may be noticed that they range from fine to full types. Some of the broader types of from five to six beams to the length, and one with V-shaped sections, have also been added.

In each case the curves represent the residuary resistance in pounds per ton of displacement; and although perhaps the total resistance might have been used with sufficient accuracy for general purposes, it was thought advisable to adopt the above system so as to conform with the usual practice of the experimental tank.

The false bottom was fixed at definite depths and all models were tested at these depths of water. As many of the models represented actual vessels and were not of the same length, they were loaded in each case to their respective load-draughts; hence the depth-length or depth-draught ratio varied in most cases. The values of the ratios are given on each curve.

In connection with the above it may be of interest to note that the various "humps" in the resistance curves occurred at practically the same speed irrespective of the length of the model, which indicates that the speed at which the maximum resistance occurs is a function of depth of water rather than size of ship.

Cross curves representing the variation of resistance in terms of depth of water are given on each diagram; also curves showing the approximate speed-length ratio at which the residuary resistance begins to increase as compared with deep water. Owing to the nature of the curves and the lack of full data, no claim is made for the absolute accuracy of these last curves, but they may be taken as representing the region of speed above which one may expect the resistance to show a marked increase. As a matter of interest a second set of curves showing the speed-length ratio in terms of depth, at which the residuary resistance is double that in deep water, have been added. Any other percentage increase may be readily obtained from the above curves.

Plates 27, 28, 29, 30, represent the results obtained for a typical set of merchant ship forms varying in prismatic coefficient from about 0.5 to 0.85. It will be noticed that the first "hump" in the curve for a given depth occurs at nearly the same speed for all types. There is, however, a tendency for the maximum to occur at a higher speed as the form of the vessel becomes finer.

Plate 28 shows the curves for two vessels of the same dimensions and practically the same prismatic coefficient or curve of sectional areas, but differing only in area of midship section, and hence block coefficient. No. I is a vessel with a full section and small rise of floor, and No. II one with a finer section and large rise of floor. The curves of residuary resistance per ton of displacement in shallow water have the same characteristics as those of deep water; but as the humps occur at earlier speeds and are much more pronounced in the shallow water, the form with the finer midship section appears to have an advantage over the fuller type, particularly at what may be termed the "practical" speeds for this form.

Plate 29 shows similar sets of curves for a slightly fuller vessel than the previous one. The same general characteristics appear to hold in both cases.

The cross curves for models No. II in Plates 28 and 29 have been omitted for sake of clearness.

Plate 30 shows a set of curves for the full type of cargo boat; but these were not carried up to the critical speed owing to the enormous increase of resistance.

The curves, Plate 31, are for a broad vessel with practically V-shaped sections throughout. In this case the vessel was tried at two draughts. It will be noticed that the "humps" occur at the same speeds for each draught, also that these are not so pronounced as in the types with fuller midship sections. This is probably due to the fact that the mean draught of the midship section is much less in this than in the previous cases.

The next two sets of curves, Plates 32 and 33, are for vessels of a rather broad and comparatively fine type.

It is often of interest to know at about what speed the first "hump" is likely to occur for a given depth of water. The speed-length ratios at which this maximum resistance may be expected, have been plotted on a depth-length ratio base in Plate 34. In this case the total resistance of the model has been taken. Other published results have been added for comparison, and from these, which are mostly for torpedo boat destroyers and vessels of a somewhat similar type it appears as if the "hump" for a given depth of water occurs at slightly higher speeds in the fuller forms.

Observations of the wave formation at the critical speeds confirm those already given by previous writers. At or near these speeds the vessel tends to form a train of waves at the stern which extends for some distance from each side of the ship and at right angles to the same. After passing this point the normal type of bow and stern wave gradually reappears.

It is possible, therefore, with the limited dimensions of the tank, that the sides may have some influence upon the results at these speeds. As, however, the first critical speed, especially at the smaller depth-length ratios, would be practically impossible of attainment in the types given, any slight error involved does not have much weight.

The writer regrets that lack of time has prevented a fuller investigation and perhaps a more detailed analysis of the results; but so far as the above information goes, it is hoped that it may throw some further light upon the somewhat obscure effect of shallow water upon the resistance of vessels.

DISCUSSION.

VICE-PRESIDENT MCFARLAND:—Gentlemen, you have heard the paper by Professor Sadler on "The Resistance of Some Merchant Ship Types in Shallow Water." Discussion is now open. It is always desirable to have a discussion, if possible.

PROF. C. H. PEABODY, *Member of Council:*— I agree with the Chairman that a discussion is very important when we can have one, and that this paper is well worthy of a discussion, but at the same time I am almost inclined to believe that discussion is impossible. Here a very important piece of work has been done and the results are given to us. We have no hesitancy in accepting the results, and having said as much as that, I do not think we can say much more.

MR. CLINTON H. CRANE, *Member:*—I should like to ask Professor Sadler if he could add to the paper a little fuller record of the forms which were tested. It seems to me that if the intention is to give us information which we can use, that a knowledge of the forms is of great importance. The results of themselves are, of course, interesting, but the results without the forms and without the actual speed at which the tests were carried on, the actual draughts of water, are not nearly so available. Perhaps I am asking more than the Professor wishes to give us, but I feel that in a paper of this sort, which, as Professor Peabody says, we have got to accept as correct, that the more information of an exact nature we can have, the better we can analyze it.

PROFESSOR SADLER:—I shall be very happy to give this information; but it occurred to me that as the number of plates in our proceedings was, perhaps, getting rather large, the information given on each curve, which is the ratio of length to breadth and breadth to draught, block, prismatic and midship section coefficients, would more or less fix the forms in the minds of most of the members. However, if it is so desired, I shall be very happy to add the information Mr. Crane wants, if the Society sees fit to publish it. I might say in connection with the speeds and depths of water, I have reduced these all to speed-length ratios, and depth-length ratios, so they are all independent of actual speeds or depths at which the tests were made. The ratio of depth of water to draught of ship is also given.

VICE-PRESIDENT MCFARLAND:—There seems to be no more discussion, and I am sure you will authorize me to extend our thanks to Professor Sadler.

We will now take up paper entitled "Experiments on the Froude," by Prof. C. H. Peabody, Member of Council.

PROFESSOR PEABODY:—Mr. President and Gentlemen, the Chairman unquestionably has in mind a very salutary rule of the Society that papers shall be read in thirty minutes. I think that rule might be modified to some extent, because I was unable to condense this paper more fully without making it obscure. At the same time, I do not intend to use even the thirty minutes allotted to me in the presentation of the paper. Those who are interested in it will have an opportunity to examine it more at leisure hereafter.

Professor Peabody then presented the paper.

EXPERIMENTS ON THE FROUDE.

By C. H. Peabody, Member of Council.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

The inception of these experiments was due to the late Dr. Charles G. Weld, of Boston, a representative of an old New England family of shipowners and an enthusiastic yachtsman. He conceived the idea that there are certain distinct advantages in making experiments by the aid of navigable models, on the resistance and propulsion of ships, and undertook to provide the means, while intrusting the execution of his ideas to the writer. The preparation of the model and its machinery and the prosecution of the experiments have been made by the staff of the Department of Naval Architecture and Marine Engineering of the Massachusetts Institute of Technology.

The prototype chosen for investigation was the Revenue Cutter Manning which was tested by the writer under favorable conditions in 1899.* The model was made one-fifth of the length of the Manning; the main dimensions of the prototype and the model are:—

	Manning.	Froude.†
Length between perpendiculars, feet....	188.0	37.60
Moulded beam, feet.....	32.0	6.40
Mean draught, feet.....	12.3	2.52
Displacement, tons.....	1,000.0	8.00
Wetted surface, square feet.....	7,273	296.00
Diameter propeller, feet.....	11.0	2.20
Pitch propeller, feet.....	12.33	2.47
Projected area of blades, square feet....	31.4	6.28

Though properly called a model, our craft, which was named the Froude is a miniature steamer of considerable size and displacement, which handles and behaves like a ship, and not at all like a steam launch.

Fig. 1, Plate 35, gives the lines of the Froude and Fig. 2, Plate 36, gives the inboard profile, showing the general arrangement of the machinery and apparatus.

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*Transactions Society Naval Architects & Marine Engineers, Vol. 7.

†In fresh water.

The hull was built by Stearns and McKay of Marblehead, Massachusetts. Mr. Stearns gave personal attention to secure essentials for our purpose without wasting attention on non-essentials.

The machinery was furnished by the General Electric Company and was placed aboard at their River Works at Lynn. The fitting and adjustment of the machinery and apparatus was done in the Charles River Basin, mainly by the mechanicians of the Institute, under the direction of Professor Harold A. Everett, who has had charge of the experiments during the summer months of 1910 and 1911.

The Froude is indirectly propelled by a gasoline electric generating set and an electric motor with a chain-drive to the propeller shaft. Both generator and motor have separate excitation on the Ward-Leonard system which gives great facility and range of control, and provides for electric measurements of power. Two measurements were made of the friction of motor, gear and propeller-shaft in 1910, when the boat was hauled up, by aid of a friction brake attached behind the propeller. In 1911 a friction brake was installed within the hull and brake tests were made with the propeller removed but otherwise under service conditions.

In order to provide for ready determination of power by electrical methods during the season of 1910, the motor, before installation, was rated in the Electrical Engineering Laboratories of the Institute. A change in method obviated the necessity of rating for 1911.

The water of the Charles River Basin is now fresh and there was very little fouling of the surface on the wooden planking of the boat, which was easily kept clean while afloat. To ensure a good condition of the surface the boat was hauled up and painted on July 21 and August 18, in the summer of 1910, and was painted twice for the summer of 1911.

The proper draughts were permanently marked on the stem and sternpost and on both sides amidships, and the displacement was adjusted by ballasting. A compensating water-tank directly over the gasoline fuel-tank made it convenient to maintain the proper displacement and trim during the runs. Observations were made to ensure that the hull did not change shape. During runs for record, only the crew (Professor Everett and assistant) were aboard and in their proper places; the writer's habit, during the first summer, was to be aboard when troubles were found or expected; during the second summer, his presence was not required.

The boat is decked at bow and stern and has a house amidships, over the machinery. The steering-wheel and the electric-controller are on the starboard side abaft the house; two slender rods on the house enable the helmsman to align the boat accurately. The principal observer manoeuvers

the boat and gives signals at the beginning and end of a run; the assistant below in the house takes the electrical reading for the measurement of power; during the first season a voltmeter and an ammeter were used for this purpose, but during the past summer a wattmeter was substituted and was found somewhat more satisfactory. The assistant also makes necessary adjustments of machinery and apparatus before and after a run.

The experiments consist in making series of progressive speed trials over a measured course an eighth of a knot long; or in some cases a course one-quarter of a knot is used. This course is parallel to the sea-wall on the Cambridge side of the Basin where the water is partially protected from the prevailing winds. The conditions for such trials are as near ideal as can be found in an unenclosed space. There is sufficient depth of water (22 feet), which is unaffected by tidal or other currents, except surface currents due to the wind. Our first year's work showed an unexpectedly large influence of the wind even on fair summer days, and accordingly the observers began work early in the morning this present year; from four to eight o'clock in the morning were favorite hours. At this time also there was little interference from other boats.

For progressive speed trials a continuous recording device is most desirable and for our purpose with only two observers it was indispensable. Our device is carried by a stand of convenient height, with rubber feet to deaden vibrations from the hull, set by the side of the propeller shaft, under the eye of the assistant observer who sees that all the pens are working properly and uses rubber stamps to indicate the beginnings and ends of runs and other information. A strip of paper six inches wide is drawn at any desired speed by a little electric motor, over guiding rolls, and across a horizontal metallic plate. Above this plate and bearing on it are a number of fountain pens with multi-colored inks; some are actuated by electro-magnets and others are connected with the mechanism which weighs the thrust of the propeller. One pen, which is controlled by a clock, marks half seconds, and another controlled by the principal observer indicates the beginnings and ends of the runs. Another pen records the revolutions of the propeller shaft. For convenience in counting every fifteenth time impulse and every tenth revolution is omitted.

The thrust of the propeller is weighed directly and a continuous record is kept by the recording-device, described in Appendix A. For this purpose the thrust-block is given a fore-and-aft motion of about three-eighths of an inch on a bed plate. The block bears against the short vertical arm of a bent-lever and lifts a long horizontal arm with a sliding weight which measures the major part of the thrust. The remnant of the thrust is

measured by an indicator spring against which the end of the long arm bears. The deflections of this spring are transferred to the recording device and recorded there on the strip of paper in the following manner: A wire is led directly up from the head of the indicator spring, and over multiplying and guiding pulleys to a pen which traverses across the strip of paper of the recording device. This pen is carried by a carriage which runs on a horizontal transverse rod with antifriction rollers; it draws a continuous curve of deflections of the spring with a scale of about 25 pounds to the inch. The entire device is kept taut by a small weight on the free end of the wire beyond the pen and its carriage. If the weighing arm is forced down out of contact with the spring, the deflection pen is at its zero and the zero-line pen can then be correctly set so that the weight for keeping the wire taut introduces no error. Considering that the major part of the thrust is weighed by the sliding weight the delicacy of the measurement of the remnant thrust by the spring and recording pen is even greater than necessary.

In order to obtain a satisfactory record of the propeller these various devices are used: the propeller shaft is free in its bearings; the thrust-block has ball-bearings; the inboard stuffing-box and the outboard steady-bearing were reamed to give a very small clearance, and the inboard gland is set up very lightly. To exclude water, the shaft-log is filled with oil with a slight head so that it oozes out slowly when the boat is running. When the boat is at rest, the motor, chain-gear and propeller shaft can easily be spun by hand. When underway a change of two pounds effective thrust will make the thrust-block crawl forward or astern; this is about three-fourths of one per cent. of the thrust at full power. The record of the thrust shows a like delicacy, and slight changes of the helm are immediately recognizable. The boat is steady on a course and the helm is practically steady during a run.

As a matter of convenience a Hutchinson electric tachometer made by the Industrial Instrument Company of Foxboro, Massachusetts, was connected with the propeller shaft in the usual way and was rated by the observing staff by comparison with the recording device. By its aid the boat could readily be run at approximately any desired speed. During brake tests the speed of the shaft was controlled by the aid of the tachometer which was found satisfactory for this purpose.

TOWING OF MODEL.

A model of the Manning one-eighth size (23.5 feet long) was made in the Institute model shop and was forwarded to the Navy Yard at Washington. Through the interest of Admiral W. L. Capps, U. S. N. (then Chief Constructor of the Navy), permission was granted to test this model and also

the propeller for the Froude at the Model Basin under the supervision of Naval Constructor D. W. Taylor, U. S. N., to whom the writer is indebted also for advice and sympathy in carrying on the tests described in this paper. The results of the towing tests of the model are given by Fig. 3, Plate 37, in which the abscissæ are speed in knots per hour and the ordinates are resistances in pounds.

TESTS OF FROUDE'S PROPELLER.

A propeller for the Froude was correctly planed according to the working drawing of the Manning's propeller, by the Fore River Shipbuilding Company and was tested under the supervision of Naval Constructor Taylor, the writer was given opportunity to witness these tests and is glad to take this occasion of expressing his admiration of the work done at the Model Basin. It will be remembered that the standard size for model propellers at the Basin is 16 inches, and that the axis of the propeller shaft in the testing apparatus is 16 inches below the surface of the water so that such models have 8 inches of water over the tips of the blades. The Froude's propeller had only 2.8 inches of water over the tips of the blades, but that condition is normal for that propeller which has nearly that immersion when in place.

Fig. 4, Plate 38, gives the torque required to drive the Froude's propeller and the thrust delivered by it, when tested in the Model Basin, together with the efficiency, all plotted on real slips of the propeller as abscissæ. This is the standard method of reporting tests at the Basin. From the torque and thrust the gross power and the effective power can be determined by the equations—

$$P = \frac{2\pi Q}{3300} \times \frac{101.33\, V_a}{p(1-s)} = \frac{A}{1000} d^2 V_a^3 \qquad (1)$$

$$E = \frac{T V \times 101.33}{33000} = \frac{B}{1000} d^2 V_a^3 \qquad (2)$$

as is explained by Naval Constructor Taylor in his "Speed and Power of Ships," page 102. In these equations, Q and T are the torque and thrust from the curves of Fig. 4, Plate 38, d and p are the diameter and pitch of the propeller in feet, while V_a is the speed of the propeller through the water in knots per hour and s is the real slip. The report from the Model Basin gave also curves of A and B on the real slips as abscissæ, but as those curves are intermediate curves, for our present purpose it has not been

thought necessary to reproduce them here. Instead there is given a transformation of the curves for A in Fig. 5, Plate 39, in which the values for

$$(1-s)^3 A$$

are plotted on the real slips for abscissæ. The transformation is as follows:

$$A = \frac{1000P}{d_2 V_a^3}; \tag{3}$$

but

$$V_a = pr(1-s) \div 101.33 \tag{4}$$

in which p is the pitch in feet as before stated, r represents the number of revolutions per minute and 101.33 is the factor for reducing knots per hour to feet per minute. From equations (3) and (4)

$$(1-s)^3 A = \frac{\overline{101.33}^3 \times 1000P}{d^2 p^3 r^3} \tag{5}$$

The curves in Fig. 4, Plate 38, can be used to determine the real slip of the propeller when working astern of the ship, so that the wake may be estimated as will be explained later.

TESTS OF 1910.

The work of our first summer was first to install, adjust and rate our machinery and instruments and to learn our limitations, and secondly to make tests with the propeller already mentioned for which the dimensions are given on page 87.

From the drawings of the Manning it appeared that the propeller was set with its hub 5 inches from the stern-post. Our normal setting of the propeller was correspondingly one inch from the stern-post. Tests were made also with the propeller-hub, successively 3 inches, 6 inches, 18 inches and 30 inches abaft the stern-post. In order to avoid interference from the rudder all tests with the three last conditions were made with twin rudders so set as not to interfere with the flow of water to or from the propellers when the boat was on a straight course.

The results of these investigations are given by Figs. 6, 7, 8, 9 and 10 on Plates 40 to 44. The abscissæ are the speeds of the boat in knots per hour reduced from the time required to run over the measured course, as given by the time pen on the tape or strip of paper from the recording device. The revolutions per minute and the thrust were also derived directly from that record.

The electrical input to the motor was computed from the readings of the voltmeter and the ammeter. From this gross input there was subtracted (1) an allowance for the electrical losses as determined from the rating of the motor in the Electrical Engineering Laboratory and (2) an allowance for the friction of motor, propeller-shaft and driving gear from the brake tests which were made as stated on page 107.

It will be noted that two curves are given for both revolutions and thrust, one with the wind and one against the wind. It is immediately evident that the mean revolution and thrust curves which should represent results that would be expected were there no wind, cannot be obtained by halving the differences, because the boat received comparatively little assistance from the wind when running with it, while there was a considerable resistance when running against the wind; the ordinary convention is that the wind resistance varies with the square of the apparent velocity of the wind observed from the deck. Making use of this convention the probable real velocity of the wind is computed by a process derived by Professor Everett and explained in Appendix C; afterwards an equation given by William Froude is applied to locate the mean thrust curve. The same proportional correction is applied to the curve for speeds and revolutions. There was then a preliminary curve drawn (not shown in this paper) of powers (corrected for electrical and frictional losses) on revolutions and from it the powers on speeds were determined and plotted as shown in the Figures 6 to 19, Plates 40 to 50.

A comparison of the thrust and power curves of the figures just described will show that the location of the propeller with regard to the stern of the boat and the broad rudder-post had a large effect on the thrust and power required to drive the boat. The same things may be seen more conveniently from the table on page 95; it is even more evident on Fig. 11, Plate 45, which is plotted with distances abaft the stern post for abscissæ and with thrust in pounds for ordinates. Each curve of which represents the thrust in pounds at a certain speed and appears to consist of two parts: (1) that for settings near the rudder post and (2) that for settings with a good clearance from the rudder-post. The curves (not the points) for settings 6 inches or more abaft the stern-post appears to be well located; those parts which represent settings less than 6 inches astern are open to question, especially at the abrupt change of form where one branch of a curve is connected with the other branch. The mind at once jumps at the conclusion that a large waste of power is due to setting the propeller in the eddy astern of the rudder post, and that when the propeller is once free from that eddy (as at the six-inch settings) there is only the normal and regular gain that may be

expected from carrying the propeller well away from the hull. This matter will be discussed more in detail in considering the thrust deduction and wake-gain.

WAKE-GAIN AND THRUST DEDUCTION.

The results of the investigations of 1910 can be conveniently presented to the mind by computing the wake, the thrust-deduction and the hull-efficiency in the conventional way as shown by the table on page 95.

In that table the speeds, powers, revolutions and thrusts are taken directly from the mean curves of Figs. 6 to 10, Plates 40 to 44.

The apparent slip is computed as usual by an equation having the form

$$s_1 = \frac{pr - 101.3V}{pr} \tag{6}$$

in which p is the pitch of the propeller in feet, r is the number of revolutions per minute and 101.3 is the factor for converting knots per hour into feet per minute.

To determine the real slip the value of

$$(1-s)^3 A$$

is computed by aid of equation (5) and the corresponding real slip is determined by aid of the curve of Fig. 5, Plate 39.

Having the real and apparent slips the wake is computed by the customary equation

$$w = 1 - \frac{1-s}{1-s_1} \tag{7}$$

in which s and s_1, are the real and apparent slips.

The resistance in pounds as given in Table I is taken directly from a curve in Fig. 25, Plate 56, which will be described with the work of 1911. It is enough to say now that this curve was obtained by towing the Froude with the propeller removed, and that the only change from the condition in 1910 was the addition of a fair-water 5 inches long that fined down the dead-wood to a width of half an inch; it is probable that this fair-water occupied the place of the eddy astern of the rudder-post. There is a chance that the resistance (1910) was actually greater than here recorded on account of the eddy, but comparison of the curve from towing the Froude with results of towing the 23.5 foot model in Washington indicates that the uncertainty is probably not large.

Table I.—Wake and Thrust Deduction.

Speed in knots.	Distance of propeller from stern-post.	Revolutions per minute.	Apparent slip.	Shaft horse-power.	$A(1-s)^3$	Real slip.	Wake.	Resistance (pounds).	Thrust (pounds).	Thrust deduction.	Hull efficiency.
7	—	351.0	0.1810	8.78	2.89	0.237	0.068	240	370	0.35	0.70
6.5	—	315.5	0.1542	6.15	2.80	0.213	0.070	188	294	0.36	0.69
6	1″	282.2	0.1263	4.24	2.67	0.186	0.068	147	232	0.37	0.68
5	—	225.0	0.0884	2.03	2.53	0.154	0.072	95	144	0.34	0.71
7	—	343.0	0.160	8.50	3.00	0.268	0.129	240	362	0.34	0.76
6.5	—	309.0	0.135	6.03	2.91	0.242	0.123	188	286	0.34	0.75
6	3″	277.8	0.111	4.24	2.83	0.220	0.123	147	228	0.36	0.73
5	—	222.6	0.0791	2.07	2.69	0.187	0.117	95	144	0.34	0.75
7	—	341.5	0.158	7.82	2.78	0.212	0.064	240	294	0.18	0.87
6.5	—	305.0	0.126	5.55	2.78	0.211	0.096	188	230	0.18	0.91
6	6″	272.5	0.0981	3.85	2.68	0.187	0.099	147	177	0.18	0.92
5	—	218.3	0.0603	1.88	2.58	0.165	0.111	95	100	0.05	1.08
7	—	344.3	0.166	7.66	2.67	0.184	0.022	240	278	0.14	0.88
6.5	—	310.5	0.141	5.60	2.66	0.180	0.045	188	214	0.12	0.94
6	18″	278.2	0.114	3.94	2.60	0.168	0.061	147	162	0.099	0.96
5	—	222.0	0.0767	1.92	2.50	0.146	0.075	95	91	−0.044	1.04
7	—	338.2	0.151	7.40	2.73	0.196	0.054	240	260	0.077	0.97
6.5	—	307.0	0.131	5.41	2.66	0.182	0.058	188	201	0.065	1.00
6	30″	277.5	0.112	3.85	2.58	0.164	0.059	147	152	0.040	1.02
5	—	224.1	0.083	1.94	2.45	0.138	0.060	95	87	−0.092	0.97

The thrust-deduction is computed by the usual method

$$t = \frac{T - R}{T} \tag{8}$$

in which T and R are the thrust and the resistance, both in pounds.

Finally the hull-efficiency is found by the equation

$$\frac{1 - t}{1 - w} \tag{9}$$

in which w is the wake and t is the thrust-deduction.

An investigation of the meaning of the results of our experiments should be preceded by a discussion of the degree of precision to be attributed to the several elements that enter into the formation of the preceding table. The speeds, revolutions and the apparent slips are determined with all desired precision; the only uncertain element is the personal equation of the observer in giving the signal at the passing of the ranges at the beginning and end of the course; even with allowance for this element the error may be estimated at a fraction of 1 per cent.

As has already been stated a variation of two pounds direct thrust of the propeller shaft could be definitely observed and measured by the thrust mechanism. At good speeds (from six to seven knots), for which the thrust is 370 to 150 pounds, the error in the determination of thrust was small; from one-half of 1 per cent. to $1\frac{1}{2}$ per cent. At the lower speeds (four knots and less) the error in the thrust is considerable, amounting in some cases to 4 per cent.

We were advised by our confreres of the Department of Electrical Engineering that the rating of our motor in the laboratory had a precision of one-half of 1 per cent. and that we might expect a like degree of accuracy in our measurements of power input to the motor. By using standardized shunts this precision was maintained for all except low powers.

During the season of 1910 we relied for determination of friction on a brake which was bolted abaft the propeller when the boat was drawn up. For various reasons the installation and running of this brake was troublesome and we were not entirely satisfied with the results. Nevertheless, a careful consideration of the results of the tests and a comparison with tests by a good brake installed in the boat in 1911 convinces us that our error is probably not greater than 1 per cent. in the determination of powers for high speeds; for low speeds the error is somewhat greater. At full power the frictional loss amounts to about 10 per cent. which is not very different from the friction commonly assigned to a steam engine. The propeller shaft

is $2\frac{1}{8}$ inches in diameter and the hole in the shaft-log is about 3 inches in diameter; as the log is filled with oil there may be considerable fluid friction.

Considering all the elements that enter into our investigations including the effect of the wind we feel justified in claiming a precision of 1 per cent. for results of tests at full power and speed (6 to 7 knots); at slower speeds and smaller powers the errors are liable to be larger, perhaps as much as 2 per cent. at 4 knots.

A corresponding degree of precision is claimed for such derived quantities as real-slip, wake, thrust-deduction and hull-efficiency; but it must be remembered that these are conventional functions which are derived in an arbitrary manner and that the interpretation of the meaning of these quantities is far from certain.

An examination of the curves of Figs. 6 to 10, Plates 40–44, will show that the operation of the apparatus and the reduction of the observations are regular and certain. All the curves are fair and they go through all the observed points. Experiments could be repeated at will definitely and satisfactorily. It will be noted that the curves of thrust show clearly a bump at about 6.5 knots, which corresponds with the bump in the curve of Fig. 3, Plate 37; it is seldom that any determination of power and speed is made with sufficient precision to locate such a bump, unless it be for torpedo boats.

There are certain anomalies especially at low powers and speeds, for which no explanation is offered. They are too well marked to be attributed to errors or uncertainties of observation or reduction, even should our estimate of errors be doubled. Among these are the curious variations of wake and especially the indication of negative thrust deductions. To my mind it appears possible that the degree of precision of our work may be sufficient to reveal real anomalies in the accepted conventions concerning the interaction of hull and propeller.

To myself the most notable feature is the small wake computed for the normal setting of the propeller 1 inch from the stern-post, more especially as the wake for the 3-inch setting, while the propeller is still affected by the eddy behind the stern-post, is what we might reasonably expect. The gain in propulsive efficiency for the latter setting as indicated by a comparison of the shaft horse-powers is only 3 per cent. As I never saw the Manning in dock and as the drawings are somewhat ambiguous it is not certain where the propeller was actually set, but any possible variation is covered by our change from 1 inch to 3 inches.

Our measurement of thrust was the most positive and certain of our measurements connected with power; consequently if the resistance of the

Froude from the towing tests can be accepted, the determination of thrust-deduction has a similar degree of positiveness. The large value of this factor and the correspondingly small value of the hull efficiency for the 1-inch and 3-inch settings, both of which may be considered to be normal are notable. The thrust deduction for the Manning is certainly less than for the Froude and probably much less because the power required for the Manning is relatively less and consequently the propeller race is relatively less. If it can be admitted that the thrust-deduction is proportional to the square of the velocity of the race then the reason for the exaggeration of thrust-deduction for a model is at once evident.

The setting of the propeller 6 inches astern of the stern-post corresponds to 30 inches astern in the Manning which would be impossible with the arrangement of the screw-aperture and the rudder-post of that ship. But for a new design such a setting would be possible and would appear to be an advantage of 12 per cent. as shown by a comparison of the shaft horse-powers.

COMPARISON WITH THE MANNING.

One of the most interesting and important results of our investigations is the comparison with the progressive speed trials of the Manning reported by the writer to this Society.* A consideration of the conditions of those trials and a study of the results by the writer and by others justifies the claim that they are reliable to the degree of precision properly attributable to such work where the power is determined by aid of the steam-engine indicator. The indicators used were of the old enclosed spring type, piped by three-way cocks to both ends of the cylinders; the power may be under-estimated with such an arrangement but the writer does not wish to venture an estimate.

In his original report the writer gave an analysis of the trials by the method proposed by Naval Constructor Taylor, estimating the wake of the ship and the efficiency of the propeller by aid of Froude's theory of the propeller. The tests of the actual propeller used on the Froude enables us to estimate the wake and thrust-deduction for that boat as has already been shown, and also to assign a probable efficiency to the propeller of the Manning. With this additional information a new analysis of the trials of the Manning is offered as a basis for comparison with the Froude.

In this analysis the fundamental data, namely, the revolutions per minute, and the indicated horse-power for speed in integral knots per hour,

*Transactions, vol. 7.

are taken from the analysis in the original report. The new analysis shows appreciable but not large divergences from the earlier one.

In order to estimate the shaft horse-power, it is now proposed to assign a mechanical efficiency of 0.90 at full speed, basing this estimate on the known efficiency of stationary engines and on the few investigations by aid of the torsion-meter on reciprocating marine engines now extant. As the engine of the Manning was in good condition and as the air-pumps were independent of the main engine this estimate is believed to be conservative. The initial reduced mean-effective pressure is taken to be 1.7 of a pound per square inch, as given in the first analysis; but the assignment of a mechanical efficiency at full-speed relegates this elusive function to a position of little importance except at low speeds where the unavoidable uncertainties are likely to cover its error. The load-friction is assumed to increase with the power, as is known to be the case for stationary engines. Thus we readily obtain the first six lines in Table II.

From the tests on the Froude the wake is estimated to be 0.07 with the propeller in the normal position; if this wake is assigned to the Manning in the analysis the real slip can be computed from the apparent slip, which latter is found in the usual way from the speed, pitch and revolutions. In general the wake of a ship will be somewhat less than that for its model; but the necessity of discussing this nice question for the case in hand can be avoided because a small variation in real slip will have only an inappreciable effect on the analysis. The reason for finding the real slip is that we may assign an efficiency to the propeller, which can be done by aid of Fig. 5, Plate 39, provided that we may assume the propeller of the Manning to have the same efficiency as was found during the tests of the propeller of the Froude at the Model Basin. Within the limits of the trials of the Manning the efficiency of its propeller is taken to be 0.68. The power delivered by the propeller to drive the ship is found by multiplying the shaft horse-power by this efficiency.

For steel ships with lean dead-wood and narrow stern-posts William Froude recommends that a hull-efficiency of unity shall be assigned. On the other hand the experiments on the Froude as analyzed on page 100, indicate a small value for the hull-efficiency when the propeller is in its normal position abaft the stern-post. In my opinion the hull-efficiency for the Manning should be appreciably larger than for the Froude as is likely to be true in any comparison of ship and model, as both wake-gain and thrust-deduction vary inversely with the size, and the latter the more rapidly. After a careful study of this problem and after making certain plausible calculations that it will not be profitable to develop here, I have concluded to use a hull-

TABLE II. ANALYSIS OF PROGRESSIVE SPEED TRIALS OF THE MANNING.

1. Speed, knots	7	8	9	10	11	12	13	14	15	16
2. Revolutions per minute	60	68.8	77.4	86.3	95.8	106.2	116.7	127.7	139.5	152.0
3. Indicated horse-power	141	194	263	354	486	671	920	1245	1661	2181
4. Initial friction power	38	44	49	55	61	68	74	81	89	97
5. Load friction power	7	9	12	17	25	35	49	67	91	121
6. Shaft horse-power	96	141	202	282	400	568	797	1097	1481	1963
7. Apparent slip	0.044	0.044	0.045	0.048	0.057	0.071	0.085	0.099	0.117	0.135
8. Real slip	0.11	0.11	0.11	0.11	0.12	0.14	0.15	0.16	0.18	0.20
9. Propeller efficiency	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
10. Propeller power	65	96	137	192	272	386	542	746	1000	1334
11. Effective power	58	86	123	173	245	346	488	671	900	1200
12. Surface friction power	52	76	105	142	187	237	299	369	449	539
13. Residual power	6	10	17	31	58	107	189	302	451	661
14. Factor for residual power	—	—	—	—	0.22	0.26	0.32	0.34	0.36	0.38
15. Speed length ratio	—	—	—	—	0.80	0.88	0.95	1.02	1.09	1.17
16. Residual power from model	—	—	—	—	126	180	271	401	592	850

efficiency of 0.9. The effective power on line eleven is therefore found by multiplying the propeller power by this factor.

In order to compare the results from these trials with the tests of the 23.5-foot model it is convenient to separate the effective power into surface friction power and residual power. Using Tideman's factors for copper in good condition the former may be calculated by the expression

$$0.00307 f S V^{n+1}$$

where the friction factor $f = 0.00943$ and the exponent $n = 1.827$; while S represents the wetted surface in square feet and V is the speed in knots per hour. The results are given on line twelve of the analysis, and the residual power is found on line thirteen. To complete the analysis the factor b is computed by aid of the formula

$$0.0307\, b \frac{D^{\frac{2}{3}}}{L} V^5$$

where D is the displacement in tons, and L is the length in feet, while V is, as before, the speed in knots. This last step, though useful when an analysis is to be used as a basis for new design, is not very interesting for our present purpose.

In order to compare the results of towing the model at the Model Basin with the trials of the Manning the residual resistance of the model was computed by allowing for the surface friction resistance, taking

$$f = 0.0092 \text{ and } n = 1.85.$$

The residual resistance was then increased by the ratio of

$$35 : 36$$

to allow for the change from fresh water in the Basin to sea-water in which the Manning was tried. In this way the residual powers of line sixteen were developed. The discrepancy between the quantities on line sixteen and line thirteen show the difference between work with a model and the analysis of a progressive speed trial.

It may be mentioned in passing that had a hull-efficiency of unity been assigned to the analysis of the trials of the Manning there would have been a close concordance between the residual resistances so computed and those derived from the tests of the 23.5-foot made at the Model Basin; but such a concordance would be quite misleading.

The question of direct interest to the shipbuilder and the naval architect is the power which should be given to a certain ship to give a desired speed. In the end all tests and trials should be made to tend toward an answer to this question. As a contribution to the answering of this question a comparison will be made of the actual observed power of the Manning with an estimation of power from the resistance of the 23.5-foot model as determined in the Model Basin, together with an estimate of the wake and the thrust-deduction from the tests on the Froude.

Thus, in the analysis on page 100, the residual power estimated from the 23.5-foot model is 850, while the surface friction power is 539, so that the effective horse-power can be estimated to be 1,389 instead of 1,200 as set down. Consequently an estimate of the power for the Manning from the 23.5-foot model would be in excess in the ratio

$$1389 \div 1200 = 1.155;$$

that is, the excess appears to be $15\frac{1}{2}$ per cent.

At first blush this discrepancy appears to be distressing, but those who have experience in this matter come to look upon it as normal instead of exceptional.

In the first place we must remember that the power varies rapidly with speed and that the comparison just made is very sensitive. Commonly the power of a ship is assumed to vary with the cube of the speed; but this relation is proper only when the speed-length ratio is less than unity. In the case in hand the speed-length ratio is 1.17 which indicates an abnormally high speed for a ship of the type of the Manning, and the power probably increases as the fourth-power of the speed if not more rapidly. If the fourth-power be taken in this case then an overestimate of 16 per cent. in the power would give only 4 per cent. excess in speed. So much for an attempt at quieting the apprehension of the shipowner. As for the naval architect if he can satisfy himself that a certain method habitually overestimates the power by a known per cent. he is nearly as well pleased as he would be with an accurate method.

For our present purpose the most desirable thing if possible would be an analysis of the discrepancy with the object of distributing it among the various elements that may influence it.

Through an inadvertence on our part the 23.5 model as tested at the Washington Model Basin was 3 per cent. light compared with the Manning on trial. It has been pointed out by Naval Constructor Taylor that the resistance of a ship does not increase with the displacement but at a slower

rate, especially when a boat is driven at high speed. The estimate of the effect of the discrepancy in question is difficult and uncertain and as 1 or 2 per cent. is not very important for our present purpose, I have preferred to let it go with other discrepancies.

To enumerate the several elements that may enter into an analysis of the discrepancy we have:

1. The computation of surface-friction resistance. No data has been published since that by William Froude in 1888; though not published it is well-known that modern experiments on paraffine and varnish for models, give close concordance with his values. But all quantities offered for computations for ships are extrapolated from Froude's results that were on surfaces not over 50 feet long. Tideman's quantities used in the analysis of the Manning were deduced by him from Froude's paper and in my opinion are unquestionably too high. Plausible values could be assigned that would close the gap of our discrepancy.

2. The steam-engine indicator is notoriously unreliable, 2 or 3 per cent. being a conservative estimate of probable error. The tendency with piping to a three-way cock is usually toward underestimating power.

3. The estimate of hull-efficiency from wake and thrust-deduction is open to doubt, and I must admit that my estimate is as favorable as circumstances indicate.

4. Though the theory of mechanical similitude indicates that resistance is proportional to the density of the medium and therefore it is customary to allow an increase in the ratio of

$$35 : 36$$

for ships in sea-water we have no experimental information on this point.

5. There is reason for questioning the accuracy of the mechanical theory of similitude as applied (*a*) to the computation of residual resistance and (*b*) to the properties of propellers, more especially as the pressure of the atmosphere is nearly constant and does not vary as the theory would indicate.

In conclusion it may be said that an estimate could be made of the influence of each element, which would be plausible if not probable, in such a way that the entire discrepancy could be explained away, but the operation would be more ingenious than ingenuous.

TESTS OF 1911.

Since the investigation of 1910 showed such an unexpectedly large influence from the broad stern-post it was decided to fit a fair-water to give

conditions more nearly like those of ordinary practice for steamships. This fair-water was 5 inches long and added just so much to the length of the boat. It is thought that it had but a small effect on the resistance of the hull. The fitting of this fair-water required the use of twin rudders to clear the propeller.

Two improvements in the apparatus were: (1) the substitution of a wattmeter for the ammeter and voltmeter of the previous year so that the observer had but one reading to take instead of two, and the placing of a water-cooled friction-brake on the propeller-shaft inside the hull.

An attempt at direct determination of the resistance was made by towing the hull without a propeller.

The main object of this year's investigation was the determination of the influence of the pitch and area of the propeller, on propulsion. For this purpose three propellers were made each 2 feet in diameter and with a projected area ratio of about 0.6 of the disk area. Except in the detail of blade contour these propellers followed the type tested by Naval Constructor Taylor and reported to this Society in the years 1904 to 1906, and in particular the blades were very thin, the thickness ratio being 0.04; as shown in Mr. Taylor's papers, moderate variations of blade contour have little if any effect on performance. Three pitch ratios were chosen, one normal, and the other two abnormal, one being much less and the other much greater than obtains in practice. These propellers are represented by Figs. 12, 13, 14 and 15, Plates 46. All were accurately planed by the Fore River Shipbuilding Company on the face and were carefully ground to a fair form at the back with sharp edges. They were, however, not formed as correctly at the back as were the propellers tested at the Model Basin and minor irregularities in some of our work may perhaps be in part traceable to this fact. After using these propellers at the area-ratio given above, they were cut down and the backs properly shaped to give the projected area-ratios shown in Table III.

The axial dimensions of the blades of the propellers varied with the pitch and consequently the length of the hub varied in a like manner as shown by Figs. 13 to 15, Plate 46. The helical width of the blades varied to a considerable degree in consequence. The propellers No. 1 and No. 3 were set with their hubs an inch abaft the fair-water; propeller No. 2 had only one-eighth-inch clearance. In consequence the propeller with the greater pitch was bodily somewhat farther aft. All of the settings, however, corresponded roughly to the 6-inch setting of 1910 which was out of the eddy of the stern-post; and for a setting in such a position Fig. 11, Plate 45, shows that there is little effect from moderate changes in axial positions.

The hubs of the propellers were not changed after the blades were cut down so that the blades with small area-ratio had somewhat more clearance from the fair-water.

In addition the propellers were all tried with their hubs set about 12 inches abaft the fair-water.

The results of the tests with these propellers are all shown by Figs. 16 to 21, Plate, 47–52, which give the revolution, thrust and the shaft horse-power plotted on speeds.

All the runs were made early in the morning to obtain favorable weather conditions; for some of the runs there was no appreciable move-

TABLE III. PROPELLERS USED IN 1911.

Type.	Pitch, feet.	Projected area-ratio.	Length of hub, inches.
No. 1	2.2	0.61	5.74
1A	2.2	0.50	5.74
1B	2.2	0.44	5.74
1C	2.2	0.36*	5.74
No. 2	3.0	0.59	7.83
2A	3.0	0.52*	7.83
2B	3.0	0.45	7.83
No. 3	1.6	0.60*	4.18
3A	1.6	0.53	4.18
3B	1.6	0.44	4.18

*Approximate.

ment of the air; during none of them was there more than a gentle breeze; nevertheless runs were made in both directions and lettered with and against the wind. The divergence of curves with and against the wind was in all cases small; the difference in revolutions or thrust was divided into thirds and one-third was added to the reading lettered with the wind. In Figs. 16 to 21, Plates 47–52, the mean curves only are shown. It is proper to say that the curves with and against the wind in every case were fair and passed through all the observed points.

A certain discrepancy may be observed in Fig. 18, Plate 49, for which the curve for the original width of blade appears to be too low throughout. There is reason to consider that the propeller in that case was set about

4 inches abaft the fair-water; that propeller followed one with a longer hub so that if by oversight the propeller shaft was not drawn back into the hull the propeller might have such a position.

It has not been possible as yet to analyze the tests of this year for wake, thrust-deduction and hull-efficiency, but the conclusion that changes of projected area-ratio and pitch have comparatively small effect on propeller performance is so inevitable that it is thought desirable to present so much of our work as is now ready; there remains a considerable amount of work done on the Froude acting as a tow-boat which must go over to some future meeting and at that time advantage may possibly be taken to amplify the report of this year.

In order to emphasize the fact that propeller changes have small effect, Fig. 22, Plate 53, has been drawn for propellers No. 1, No. 2 and No. 3 at the normal setting. The previous figures show that the power curves were but slightly affected by width of the blade; consequently one mean curve has been drawn for each pitch; these three mean curves show surprisingly small variation. A similar diagram for the 12-inch settings would show even closer concordance.

Now the variations of both pitch and width of blades are much greater than are likely to be assigned to any given design even by engineers who differ widely in practice, consequently we may conclude that the practical efficiency of well designed propellers is very little affected by ordinary variations of pitch and width of blades; to this conclusion may be added that all propellers having oval forms of blades are sensibly equal in efficiency.

It is thought that it would be interesting to show two typical diagrams with all observed points recorded; one, Fig. 23, Plate 54, represents tests made on a day when there was no appreciable wind; the other, Fig. 24, Plate 55, represents tests made when the wind varied from east to north in three hours, and blew at times with a velocity of 7 knots per hour.

TOWING OF THE FROUDE.

A direct determination of the resistance of the Froude was made by towing with the propeller removed, but otherwise in normal condition. In anticipation a Pitot tube and a registering gauge was fitted; the tube which was three-quarters of an inch in diameter and had a hole one-fourth of an inch in diameter, was protruded directly down 12 inches below the planking under the center of buoyancy. The tube and gauge were rated by running the Froude a large number of times (160) over the measured course taking times in the usual way by the recording device.

Having rated the Pitot tube it was used to register the speed of the Froude through the water when towed by the tug-boat Wm. G. Williams, which is about 62 feet long and has a draught of about 6 feet. The tow-line was 200 feet long and in all cases was kept clear of the water; a light line was used for low speeds and a heavier line at higher speeds. The race of the propeller was distinctly felt being about 5 per cent. at 6 to 7 knots.

The resistances at various speeds are shown by Fig. 25, Plate 56, which gives in all three curves: (1) the proper corrected curve of resistance on speeds; (2) the uncorrected curve of resistance on the indicated speeds by the Pitot tube, and (3) the resistance as estimated from the model (23.5 feet) when towed in the Washington Model Basin. The latter curve was determined by applying the theory of similitude on the basis of displacement, not making separate computations for frictional and residual resistances. The discrepancy between our experimental curve and the curve deduced from the 23.5-foot model is not more than may reasonably be charged to the difference in surface; the hull of the Froude was planked and caulked and painted with antifouling paint, while the model had a fair double skin, painted and varnished.

BRAKE TESTS OF 1911.

A brake with a cast-iron wheel 10 inches in diameter and having a face 8 inches wide was attached to the propeller shaft at a convenient place and arranged for continuous water cooling so that it could run steadily at any given condition half an hour or more. The brake arm was 30 inches long and pulled on a spring balance that could be read to one-half pound; the load varied from 10 to 95 pounds for the several conditions.

A complete investigation was made for each of the three propellers having the three several pitches mentioned in this report; because the revolution corresponding to a given power varied with the pitch. Having the input to the motor for a given power and speed and the brake reading for those conditions, the shaft horse-power could be found directly, without depending on a rating of the motor. Fig. 26, Plate 57, gives the tests by the brake for the conditions of Propeller No. 1, both for the normal conditions and when the Froude was used as a tow-boat.

ACKNOWLEDGMENTS.

As was said at the beginning of this paper the tests on the Froude were proposed and financed by Dr. Charles G. Weld and this addition to our knowledge of the problems of propulsion is due primarily to him.

During the preparation of plans for the work the writer consulted with Naval Constructor Taylor and with the officers of the Fore River Shipbuilding Company who gave him access to their private records of tests, and was assisted by his colleagues, Professor Walter S. Leland and Professor Harold A. Everett.

The construction and installation of the machinery and apparatus and the execution of the tests has been under the direction of Professor Everett to whom very much of the credit of the work is due. He was assisted by Mr. L. B. Chapman and by Mr. G. G. Holbrook. The work is of a nature that appeals to men of their training and profession and enthusiasm and fidelity to the work might be expected, but only sterling character could meet, as they have done, hard work and discouragement cheerfully and resourcefully. The greatest reward of such work is to bring it to successful issue.

APPENDIX A.

THRUST MECHANISM.

The thrust mechanism which is an essential feature of our apparatus and which has some special features is represented by Figs. 27, 28 and 29, Plates 58–59. In order to allow the propeller shaft to be shifted fore-and-aft it was threaded for its entire length, save for the part that might be in the shaft-log. On the shaft, as shown by Fig. 27, Plate 58, there was a composition sleeve which was locked by a nut both forward and aft, when the shaft was set in any desired position. There was one thrust collar at the middle of the sleeve with adjustable steel races for the balls that carried the thrust to the thrust block. Near the ends of the sleeve were cylinderical races with balls to carry the weight of the shaft.

The bent-lever for weighing the thrust is shown by this figure and by Figs. 28 and 29, Plates 58–59. The long horizontal arm (shown broken) is 40 inches long; the short horizontal arm carries a counter-weight for use in making adjustments. The short vertical rod is forked and bears directly against the thrust-block knife edges; at the bearing surface the short arm has hard steel plates to guard against indentation of the knife-edges. The shell of the thrust block is split diametrically for convenience in construction and assembling. It carries two lugs on each side as shown by dotted lines in Fig. 27, Plate 58, and by full lines in Fig. 28, Plate 58. These lugs are split and there are four hard steel knife edges inserted with their edges in the horizontal diametrical plane. The bent-lever has a ball-bearing pivot as shown by Fig. 29, Plate 59. The entire thrust-block rests on a bed-plate and has a fore-and-aft motion of three-eighths of an inch; this is more than necessary so that troublesome adjustments may be avoided. When the boat was maneuvering to come on the course the block could be wedged fast, and when on the course it was cast loose.

As already described, the major part of the thrust was counterbalanced by a large sliding weight on the long arm of the bent-lever. To allow for and measure minor fluctuations the extreme end of the bent-lever bore against an indicator spring that was secured to the frame of the boat. The deflections of this spring were carried by a light wire over multiplying and guiding pulleys to a pen that traversed across the tape of the recording

device. To set this pen at its zero it was sufficient to force the weighing lever down, out of contact with the indicator spring. The scale of the pen record was found by giving the indicator spring a measured deflection. Since only a fraction of the thrust was recorded by the thrust-pen fussy adjustments were unnecessary.

This thrust mechanism was found to be sensitive and at the same time positive and worked without trouble, and almost without attention.

APPENDIX B.

Recording Chronograph used in Experiments on the Launch Froude at the Massachusetts Institute of Technology.

By H. A. Everett, Member.

In order to obtain a continuous record and to keep the operating force during experimental runs down to the minimum, it was necessary that nearly all the measurements be made self registering. With this end in view a recording apparatus was designed which should give a continuous record of time, crossing signal (for start and finish of run) revolutions (of the propeller shaft) and thrust of the propeller.

The records are made upon a continuous band of paper which passes under pens operated by electro-magnets. The armatures of these magnets move the pens every time a circuit is closed or opened, which makes a notch in the straight line that the pen is normally tracing. Figure 30, Plate 60, shows several views of the recording chronograph as finally built and as used on the Froude. *A*, is the roll of paper which is drawn by the motor *M*, over the flat plate table *T*, and above this are shown the sockets for the pens with one pen in place. Operating the pens are the electro-magnets *E*, *E*, etc., of which there are six.

The roll of paper is 6 inches wide and is hung in ball-bearings directly under the pens. The diameter of the full rolls is approximately 11 inches and they contain about 2,000 yards of paper, enough to last from two to three weeks under normal running conditions.

The paper is drawn along by a small (one one-hundredth horse-power) electric motor designed for 110 volts direct current which was available on the Froude and which is practically standard for marine installations. This was desirable as it permitted the use of the chronograph on trial trips of other vessels. By means of a variable resistance in the motor line the speed of the tape could be varied to give as open a record on the tape as was desired. In this connection it is well to note that as the record of time is continuously drawn on the tape the necessity for a uniform motor speed is eliminated and though the motor ran very uniformly for any given setting it was merely incidental and had no effect on accuracy.

Figure 31 shows a specimen of the tape record, *AA* is the time record which is made by a clock opening and closing the pen circuit every half

second so that from the beginning of one notch to the corresponding part of the next notch represents one half second. To facilitate counting every fifteenth contact is omitted which gives the broad interval and these broad intervals correspond to eighths of a minute. The clock is also arranged to give quarter second contacts if desired but, as the half-second record can easily be read to tenths of a second, the shorter intervals were seldom used.

BB is the record of the revolutions of the propeller shaft and for this the contacts were made from a toothed wheel which was operated by a ratchet and pawl which in turn were operated by a cam, on the main shaft. Every tenth tooth was omitted which makes the broad interval and facilitates counting. Duplicate pens were provided for twin or triple screws and

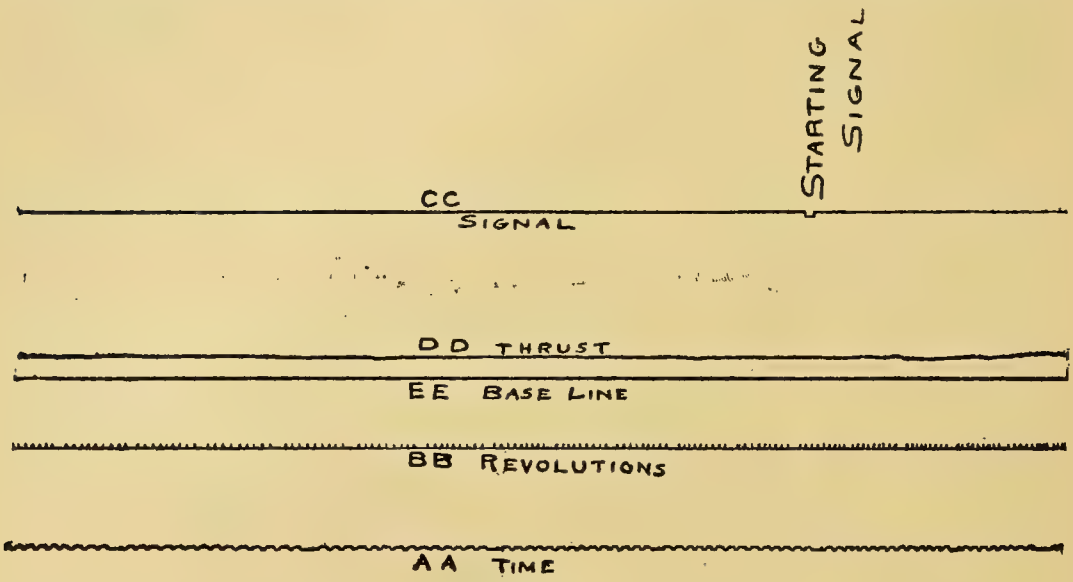


FIG. 31.

though not used on the Froude gave very interesting records on several trial trips of full sized ships.

The record of the crossing signal is given at *CC* and for this a contact was pressed by hand on crossing the start and finish ranges. Counting the time interval on *AA* between these two signals gives the time on the course and therefore the speed.

For the thrust of the propeller shaft, electrical contacts could not be used, as the motion of the scale beam lever had to be transferred directly to the tape. The major part of the thrust was taken up by the scale beam weight and a small spring was used to maintain the arm horizontal, thereby taking up the rest of the thrust. The deflection of this spring when magni-

fied in the ratio of about 9 to 1 was transmitted directly to the tape by means of a very fine wire attached to the carriage holding the pen. This carriage consisted of a rod which carried the pen socket, S_1, and which rested on pin-bearing pulleys P at each side of the table T (see Fig. 30). These permitted a very free movement across the table. As the spring deflected, the carriage traveled across the paper at right angles to its line of motion and traced a curve thereon; the heighth of which gave a measure of the thrust to be added to that taken up by scale beam weight. The scale for this curve was about 25 pounds to the inch.

DD is the record of the thrust pen drawn from *EE* as a base line by a pen in the socket S_1. The line base was drawn by the pen in S_2 and was adjusted to agree with the zero deflection of the spring. The zero was tested between each run by pushing the scale beam lever down until it was out of contact with the spring.

Fountain pens of special construction were used for all the records and they worked perfectly, on several instances when the apparatus was used on progressive speed trials they drew continuous lines for about eight hours.

APPENDIX C.

A Method of Allowing for Wind Resistance.

By H. A. Everett, Member.

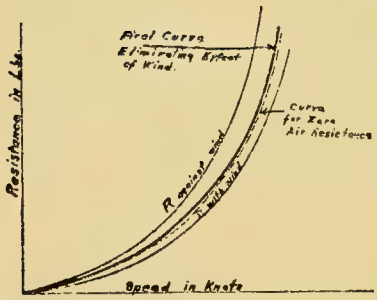


Fig. 32.

Let R_w = Wind resistance.
V_w = Speed of wind past the ship.
V'_w = Speed of wind.
V = Speed of ship.
R = Resistance of ship.

When the ship is going against the wind;

$$V_w = V + V'_w$$

and when going with the wind,

$$V_w = V - V'_w.$$

Froude gives for wind resistance,

$$R_w = KA\,V^2_w$$

where K is a constant and A is the area of the transverse contour above the L. W. L.

$$\therefore \qquad R_w \propto V^2_w$$

From the experimental curves we get R_w and R_a at any desired speed of the ship V.

Then—

$$R_{\text{against}} = R + R_w \text{ and} \tag{1}$$

$$R_{\text{with}} = R - R_w \tag{2}$$

$$R_{\text{against}} = R + KA\,(V + V'_w)^2 \tag{3}$$

$$R_{\text{with}} = R - KA\,(V - V'_w) \tag{4}$$

$$R_{\text{against}} - R_{\text{with}} = KA\,\{(V + V'_w)^2 + (V - V'_w)^2\}$$

$$\frac{R_{\text{against}} - R_{\text{with}}}{KA} = (V + V'_w)^2 + (V - V'_w)^2$$

Completing the square gives,

$$\frac{R_{\text{against}}-R_{\text{with}}}{KA}+2\,(V+V'_w)\,(V-V'_w)=\{(V+V'_w)+(V-V'_w)\}^2$$

$$\frac{R_{\text{against}}-R_{\text{with}}}{KA}+2\,V^2-2\,V'^2_w=(2\,V)^2$$
$$=4\,V^2$$

$$\frac{R_{\text{against}}-R_{\text{with}}}{KA}-4\,V^2+2\,V^2=2\,V_w'^2$$

$$V'_w=\sqrt{\frac{R_{\text{against}}-R_{\text{with}}}{2\,KA}-V_2}$$

To illustrate the use of this method, in the case of the experimental model Froude, $2\,KA=.34$.

On the runs of August 23 at 7 knots the thrust with the wind was 286 pounds and against the wind was 322 pounds. Whence,

$$V'_w=\sqrt{\frac{322-286}{\cdot 34}-49}=\sqrt{\frac{36}{\cdot 34}-49}=7\cdot 5$$

Therefore the speed of the wind $V'_w=7.5$ knots.

With the velocity of the wind known it is now possible by using Froude's formula to figure the wind resistance of the boat at any speed in either direction, as for instance at 7 knots.

$$R_{w\ \text{against}}=0.17\ (14.5)^2=35.7$$
$$R_{w\ \text{with}}\ =0.17\ (0.5)^2\ =\ 0.4$$

Now the total divergence between the two curves at 7 knots should be equal to the sum of these quantities.

$$35.7+0.4=36.1 \text{ pounds.}$$

As a matter of fact, the difference was actually 36 pounds.

Subtracting the wind resistance from the curve with the wind, will give a curve for zero air resistance; that is for a ship always accompanied by air going at the same velocity that the ship is.

Now to the curve of zero air resistance should be added the normal air resistance due to the speed of the ship through the still air which gives the heavy full line curve of Fig. 32, and this is a curve from which wind influence has been eliminated.

It is interesting to note that the speed of the wind as solved by the above method agreed closely with that speed of the Froude where the entry in the log reads "V of Froude same as V of wind."

DISCUSSION.

VICE-PRESIDENT MCFARLAND:—Gentlemen, Professor Peabody's paper on "Experiments on the Froude" is now open for discussion.

PROF. H. C. SADLER, *Member of Council:*—Mr. Chairman and Gentlemen, I regret I have not been able to examine this paper in the detail I should like, and which I intend to do in the future, but I think that Professor Peabody is to be congratulated on the good work he is doing in this connection. I have always felt that the determination of wake in the ordinary model tank was open to a certain amount of doubt. The quantities measured are comparatively small, the propellers used are also small, and I think that estimates of wake may not, under these conditions, be very accurate.

Here we have a much larger scale experiment than is possible with the ordinary tank, and I think in that way, perhaps, Professor Peabody may be able to give us in the future some more definite values of wake, as it is ordinarily understood, than that which we have at present.

The results shown in Table 9 are very suggestive in that connection, as well as the diagram in Fig. 11, Plate 45, showing the variation of the wake in terms of distance of the propeller from the ship.

The influence of the form of the vessel upon wake is another point which I hope Professor Peabody may be able to take up in the near future, if it is possible to remodel the stern of the vessel without much trouble; for example make changes in the stern water lines and find the effect of these upon wake, and I think it will be of great advantage as throwing further light upon the stream line flow at the stern of the ship.

MR. CLINTON H. CRANE, *Member:*—Mr. Peabody's experiments with the Froude are extremely interesting. I do not think that I have the right to claim to being the father of such a method, but back in 1905, in connection with a paper which I read, I suggested the great value of experiments performed on small launches with reference to the effect on larger sized vessels.

On the other side, when I was on the East Coast, I saw a model which had been made of the Mauretania, and run back and forth in one of the docks, in an endeavor to obtain a good deal of the sort of data which Mr. Peabody has given to us, and which I believe the experimenters on the Mauretania model kept to themselves.

That same year I saw a large model, about 50 feet long, at Denny's and they said, in spite of their model basin, they felt for certain propeller problems it was necessary to carry on tests similar to those Professor Peabody carried on.

We have found in our own experiments that what we have done with the smaller launches has been of the greatest value in predicting, not only the speed, but the behavior of the larger size vessels. Launches from 20 feet to 40 feet long have given us most valuable information, and in banking on what we found from them we have not gone wrong.

I believe there is a possibility of small errors creeping into any such investigation. I do not believe a model ship by even the best shipyard will be an exact representation of the large sized ship. She will be near enough for practical purposes, but there may be differences which would tend to account for the fifteen per cent.

Moreover, the surface of a model which is kept in the water for testing, very soon loses a definite factor. We find in our racing boats that after a week to ten days, it is absolutely necessary to take the boat and put her in fresh condition, otherwise she is badly beaten.

I am only giving these thoughts as an addition to Mr. Peabody's paper, which seems to me to be of very great value to the members of this society, and to every student of naval architecture, and I regret with Professor Peabody that Dr. Weld is no longer living, and I hope that this may not be the stoppage of these valuable experiments.

Mr. William T. Donnelly, *Member:*—I do not know that I can add anything particular to the discussion, but I would like to ask Professor Peabody if he can give us some information as to what, in his judgment, was the nature of the improvement due to the moving of the propeller farther from the stern-post. Was the increased efficiency due entirely to eliminating the action of the stern-post or was it partially due to the moving of the propeller from the after-body of the ship, thus reducing the influence of the propeller from the hull resistance.

It would seem that the reason propellers are kept so close against the stern-post is the matter of mechanical construction; that is, to obtain rigidity. The important point to be considered is the amount of saving that will be brought about by elaborating the design so as to carry the propeller further away from the stern-post, and what may be of equal or more importance, further away from the after-body of the vessel, where the propeller will have less tendency to reduce the water pressure on the after lines.

I should be pleased if Professor Peabody could throw any additional light on these points.

Vice-President McFarland:—Is there any one else who desires to speak on the subject? If not, we will ask Professor Peabody to make his reply.

Professor Peabody:—I want to thank Professor Sadler for the criticism and appreciation he has given of this paper. I also want an opportunity to thank him

now, as I could not consistently do in my acknowledgments, for giving me a very important piece of work in connection with the experiment I was carrying on.

Having anticipated this difficulty about surface friction, I fondly imagined I could do some work on that on my own behalf. I will not go into the details of that, because it was a failure. Professor Sadler very kindly undertook with his model basin at Ann Arbor to find out what the trouble was and show me. I can thank him for that now, but as I had to drop out my own work in that line from presentation, it did not seem possible to include his name in the statement which I desired to make.

In the suggestions made by Mr. Crane, there is no question that in his work on launches he may proceed from small launches to larger launches with the greatest possible advantage. That is also what has been done in the cases he referred to, in the model of the Mauretania, the model tested by Denny's and the work done upon the Froude. That is, these were all models of a full sized ship. Let us note, however, that they are not toys. Perhaps we believe that models 20 feet long are not toys. The model of the Manning had a displacement of 8 tons. She handled like a little steamer, and especially when she was given twin rudders to enable the propeller to be placed farther astern, she behaved rather badly. I speak of this, because I believe that is what Mr. Crane has in mind that from experiments on the smaller craft you can get the greatest advantage in the design of larger craft of the same sort. Of course, you cannot go from launches to ships—a launch is not a ship on a small scale; it is a different craft. I do not think that accidental differences in form or in displacement of models, will have any appreciable effect upon the experiments, when they are carried out with reasonable care.

As for the surface of the Froude, the Charles River Basin, as was stated in the paper, is now fresh water, and we have taken pains to have the Froude kept painted and repainted, also keeping the surfaces scrubbed clean; as a matter of fact, the surface was clean the whole season and was not subject to fouling, and there was no appreciable loss of efficiency from that cause.

As to the question asked by Mr. Donnelly, the experiments and especially the diagram to which he referred, show very clearly that on the Froude, and probably also on the Manning, the prototype, the propeller was much influenced by being set immediately astern of a wide stern post.

It is also apparent from the experiments on the Froude, with and without the fair-water that with the propeller well astern (namely, six inches, which corresponds to the thirty inches on the Manning), the resistance probably was not due to the interference of the stern post, but was due to the general effect of the propeller upon the form of the stern.

It would be very desirable, as Professor Sadler indicated, that tests should be made with different forms of sterns and different hulls. Although I regret the loss of my friend Dr. Weld I am not hopeless that we may be able to carry on the work in which he was so much interested. I thank you.

VICE-PRESIDENT MCFARLAND:—It is very evident, from the reading of the paper, and also the remarks of those here who are competent to judge, that this is a paper of unusual value, and I am sure you will all want to accord a hearty vote of thanks to Professor Peabody for his paper.

We will now take up the paper entitled, "The Effect of Waves Upon a Taffrail Log," by Prof. Harold A. Everett, a Member of the Society.

Professor Everett presented the paper.

THE EFFECT OF WAVES UPON A TAFFRAIL LOG.

By Professor Harold A. Everett, Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

Taffrail logs have had, in general, a bad name for accuracy, though the reasons advanced have seemed hardly sufficient to cover the gross errors which occasionally appear. In speed trials they have been practically abandoned as a means of accurately measuring speed through the water, though the need for this information is great. At the Institute of Technology we have used them occasionally in conjunction with other means for measuring speed and invariably with erratic results. The causes of this erratic behavior have been variously ascribed to poor mechanical construction, wake, and torsional elasticity of the log line.

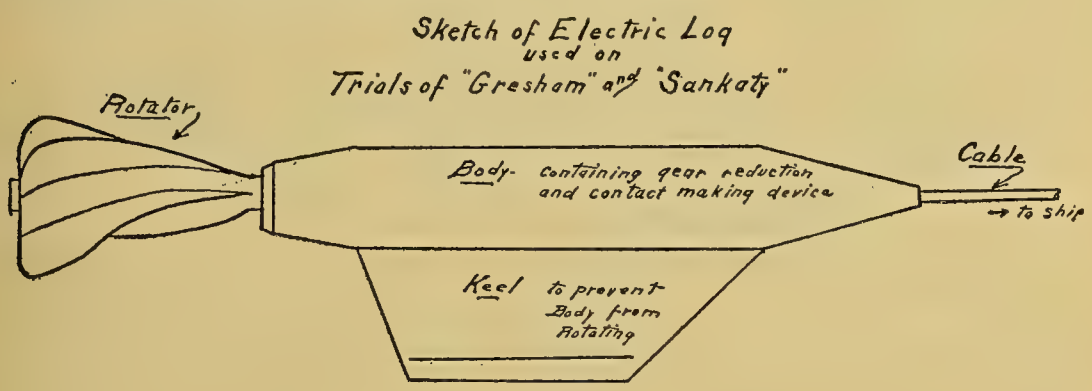


Fig. 1.

Some years ago the Institute purchased a log intended to eliminate the first and last sources of error and in order to do away with the second it was proposed to tow this log from a long spar projecting from the side of the ship. This log, a cut of which is shown above (Fig. 1), had the ordinary form of rotator, but it was attached directly to a body which did not rotate and which was towed from the taffrail by a long cable with two wires contained therein. The rotator drove through a mechanical reduction gear a shaft carrying a cam that made and broke the circuit in the cable. This make and break by means of an electro-magnet threw a counter in the dial located on board the ship which read directly in 20ths of a knot. Runs were made with this log towed from the end of a 25-foot boom and still erratic behavior was

noticed. As the mechanical construction of the log seemed open to suspicion it was most carefully rebuilt in the shop of the Institute and then tried out on the progressive speed trials of the United States Revenue Cutter Gresham over the Government course at Provincetown in 1910. The results of these trials showed such an erratic behavior of the log constant that it led the author to suspect that another source of trouble than any of those previously mentioned was the real cause; namely, the effect of the waves which the ship carries along with itself.

Leaving the results of these trials for a moment let us consider the effect upon such a log that might be expected from the waves maintained by the ship.

Figure 2 shows the profile of a trochoidal wave traveling across the page from right to left. This wave is composed of particles each rotating in a circular orbit and the orbits of three of these particles are shown, one at the hollow, one at half way from hollow to crest and one at the crest. Now

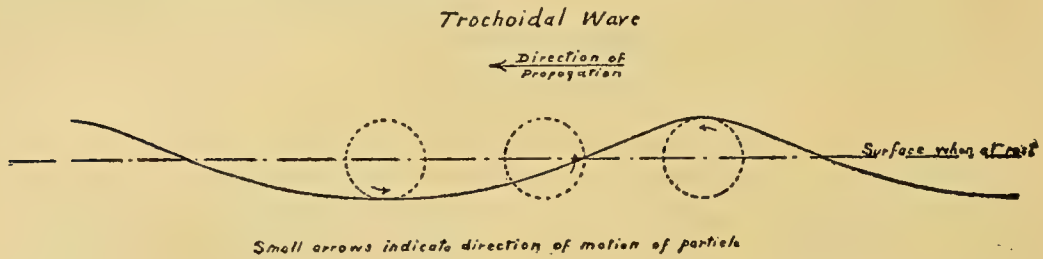


FIG. 2.

if a log were to be dragged in this wave at the same speed that the wave was going and from a line of such length that it came at a hollow, we should expect that the rotator would be spun faster than it would be in still water, as the particles are moving away from the ship. In other words we should expect the log to overrun in its readings and the factor by which it would be necessary to multiply the log reading to get correct speed would be less than what it would be in still water. Conversely if the log were towed on a crest this factor would be larger than when in still water and half way between (the middle particle in Fig. 2) there would be no effect, as the particles are moving at right angles to the log and should not affect it.

All ships when under way maintain two systems of waves, a bow system and a stern system each consisting of diagonal waves on each side with transverse waves which terminate in these diagonal waves as indicated in Fig. 3. These transverse waves are apparently nearly trochoidal waves and considering only the stern wave system, we should expect to find a log which was towed behind a ship, alternately overrunning and underrunning as the ship

gradually increased its speed. These variations would correspond to the successive traveling of hollow and crest past the log, as the transverse waves behind the ship gradually lengthen with the increasing speed, and if a plot were to be made of this log factor, on speed of the ship as abscissæ, it would have the general appearance of Fig. 4, which is made for a log towed 255 feet behind a ship of 188 feet length between perpendiculars.

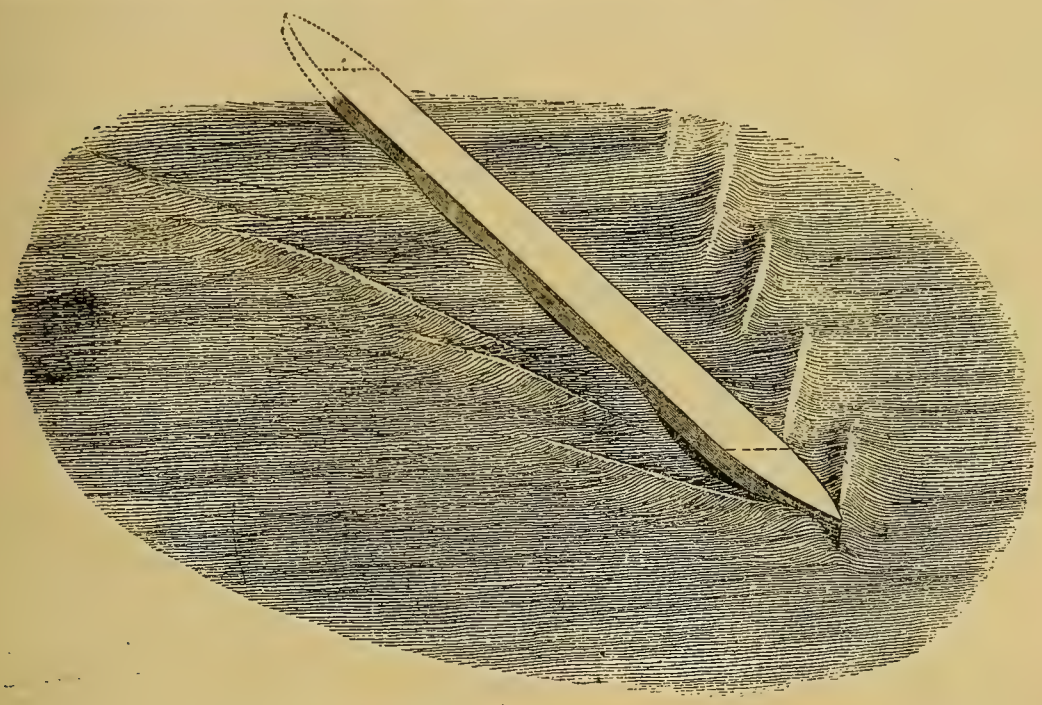


FIG. 3.

The construction of this curve can be made evident by looking at Fig. 5 which shows the stern wave system (according to the trochoidal wave theory) of a ship of the above length at several speeds. At the first speed (7.8 knots), the log is in a hollow so the log factor (the factor the log speed is multiplied by to get the correct speed) is below the normal value for still water. If

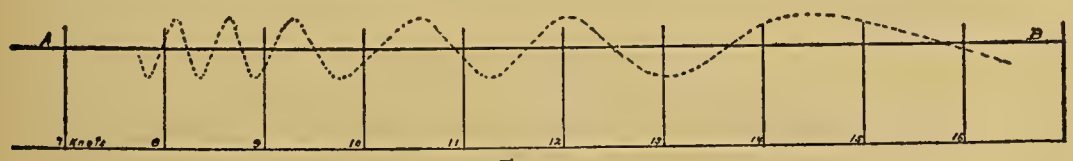


FIG. 4.

A-B in Fig. 4, represents this still water value then the curve of Fig. 4 would begin with a hollow at 7.8 knots. Referring again to Fig. 5, at 9.2 knots speed there are but 6 wave crests between the log and the stern post while

at 7.8 knots there were 8 crests so that in going from the former speed to the latter two crests have passed under the log and there should be two peaks to the log factor curve of Fig. 4 between 7.8 knots and 9.2 knots. Also at 9.2 knots, according to Fig. 5, the log is nearly on a crest so the log factor should be nearly at the top of its upward variation; continuing in this way Fig. 4 is completed.

So far only the stern system has been considered, now if the bow system be brought into the conception it injects a decided modification in the pre-

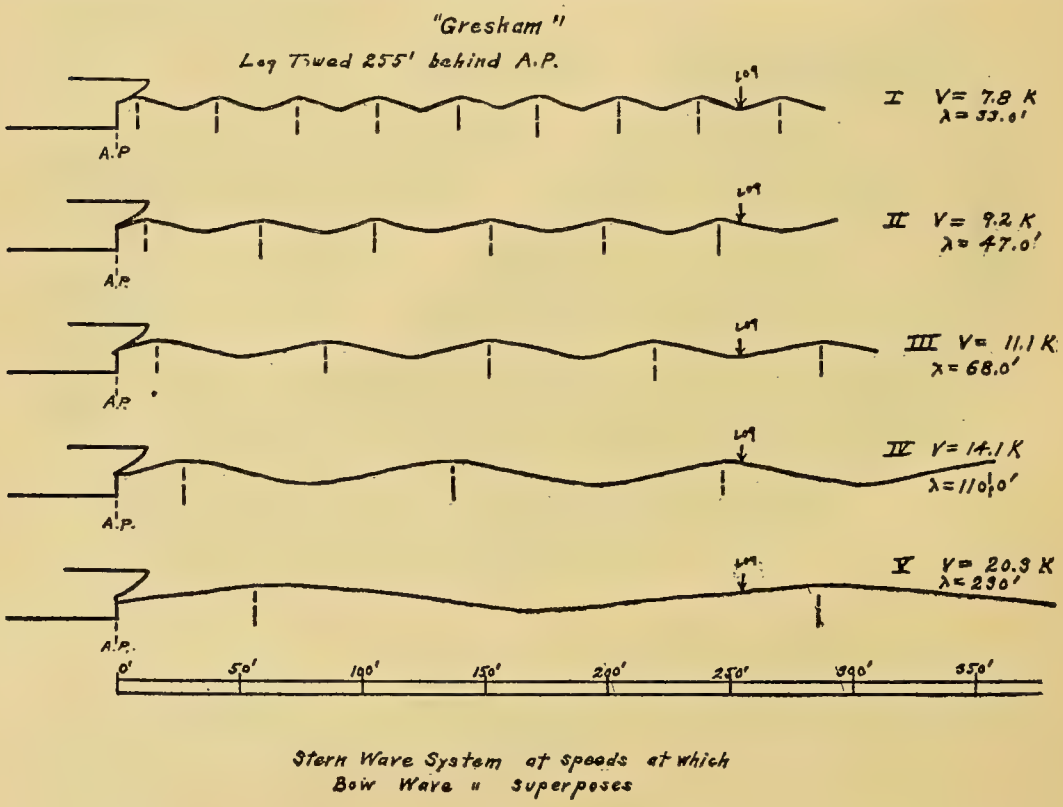


FIG. 5.

ceding figure (Fig. 4). As a ship is propelled through the water at gradually increasing speed the bow wave system, when it reaches the stern, alternately increases and decreases the height of the transverse waves of the resultant stern system. If the bow waves were of equal height to the stern waves, at the time of their reaching the stern system, the resultant waves would be twice as high as the individual waves when the two systems came crest to crest and would be nil when they came crest to hollow. The speeds of the ship at which these two events occur can be figured with reasonable

exactness; they, of course, correspond to the speeds of maximum and minimum wave interference and the theoretical conception of these speeds has been verified by experimental work in towing basins and elsewhere. The speed of a trochoidal wave is definitely represented by the following formula:

$$c = \frac{\sqrt{\lambda}}{\sqrt{\frac{2\pi}{g}}} \quad \therefore \; c = 1.34\sqrt{\lambda}$$

where

$c =$ speed of advance of crest, in knots.
$g =$ acceleration due to gravity in feet per second.
$\lambda =$ length from crest to crest of one wave.

The wave making length of a ship is slightly larger than the length between perpendiculars from 1.05 to 1.2 according to Naval Constructor D. W. Taylor, U. S. N.,* and if we let m represent this factor and L the length between perpendiculars of the ship $\frac{mL}{\lambda}$ will be the number of waves there are between the first transverse crest of the bow and the first transverse crest of the stern systems. When this is a whole number the resultant waves at the stern are at their maximum height and when it has a value of half units the waves will be neutralized.

Now as $c = 1.34\sqrt{\lambda}$

and

$$\frac{mL}{\lambda} = \text{number of waves}$$

we have

$$c^2 = \overline{1.34}^2 \lambda$$

$$= \frac{1.795\, mL}{\frac{mL}{\lambda}}$$

and

$$\frac{mL}{\lambda} = \text{number of waves} = \frac{1.795\, mL}{c^2}$$

whence

$$\frac{mL}{\lambda} = \frac{1.795\, m}{\left[\frac{c}{\sqrt{L}}\right]^2}$$

so that assuming different numbers of waves and solving for the speed of the ship corresponding, we get the results shown in Table I for a ship 188 feet long between perpendiculars.

From this, at the speeds of 14.05, 11.05, 9.18 and 7.75 knots we should expect the variation of the log constant from the still-water line (A-B) to

*Speed and Power of Ships.

be nearly doubled and at the speeds of 16.5, 12.35, 10.0 and 8.35 we should expect the variation to be nearly zero.

Fig. 6 is drawn amplifying and minimizing the variations shown in Fig. 4 to correspond with the maxima and minima at the above figured speeds.

Now suppose that the log did not have a uniform rate in still water,

TABLE I.

$\frac{mL}{\lambda}$	$\frac{c}{\sqrt{L}}$	c	Wave height will be.	λ
1.0	1.480	20.3	Maximum.	230 feet.
1.5	1.205	16.5	Minimum.	—
2.0	1.025	14.05	Maximum.	110 feet.
2.5	.904	12.35	Minimum.	—
3.0	.808	11.05	Maximum.	68 feet.
3.5	.730	10.0	Minimum.	—
4.0	.67	9.18	Maximum.	47 feet.
4.5	.61	8.35	Minimum.	—
5.0	.57	7.75	Maximum.	33 feet.

which is usually the case, but that at slow speeds it had a greater error; then instead of the curve of Fig. 6 being plotted about a straight line *A–B* it would be plotted about the curved line *A–B* of Fig. 7, where *A–B* would represent the rate of the log in still water. This, then (Fig. 7) would give a curve that would show the variation in log factor for speeds from 8 knots

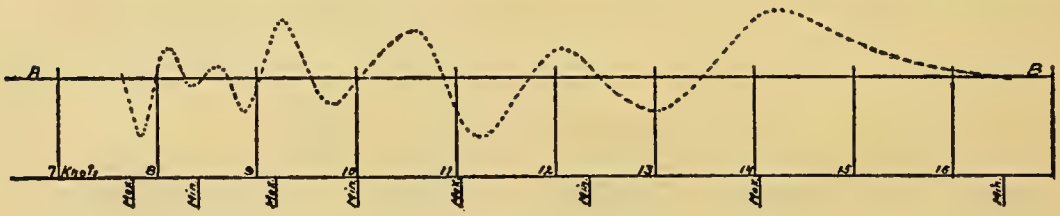


FIG. 6.

to 16 knots of a log towed 255 feet astern of the ship under discussion, provided the log had a quiet-water calibration corresponding to *A–B*, of Fig. 7.

On the progressive speed trials of the U. S. R. C. Gresham (which had a length between perpendiculars = 188 feet), the recording log previously described was towed 255 feet behind the stern post and the speeds over the course were taken by a recording chronograph (described in Professor C. H. Peabody's paper read at this meeting) on which were recorded also the contacts made by the electric log every one-twentieth of a knot. The

curves of speed and R. P. M., with and against the wind, and the mean curve, are given on Plates 61 and 62, and from the tape record, the log speed on each run was taken. The results are given in Table II.

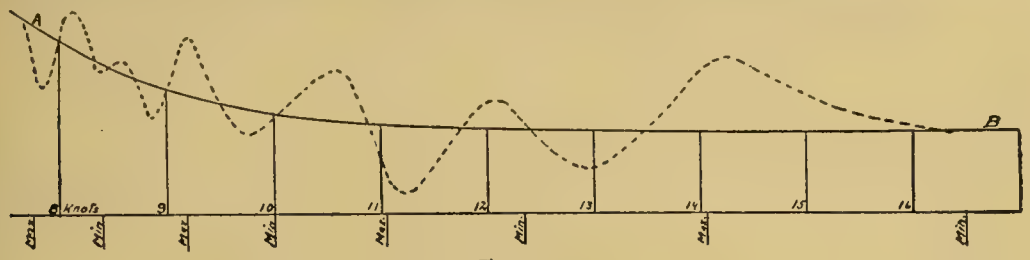


FIG. 7.

TABLE II.—U. S. R. C. GRESHAM.*

Run No.	V by log.	V from mean curve.	Ratio $\frac{V_{curve}}{V_{log.}}$
1	3.99	5.49	1.378
2	3.92	5.39	1.375
3	3.49	5.19	1.489
4	3.44	5.13	1.491
5	2.69	5.05	1.879
6	7.36	8.20	1.170
7	7.13	8.31	1.167
8	6.92	8.19	1.185
9	10.45	11.00	1.052
10	9.55	10.81	1.133
11	9.62	10.83	1.126
12	9.63	10.84	1.128
13	†	†	†
14	12.71	13.60	1.069
15	12.65	13.45	1.063
16	12.46	13.35	1.072
17	13.36	14.90	1.115
18	12.95	14.60	1.127
19	14.20	15.42	1.087
20	13.97	15.41	1.100
21	‡	‡	‡

*For dimensions see Table IV.
†Speed accidentally altered during run.
‡Log disconnected.

Plotting the ratios of V_{curve} to V_{log} on the speed of the ship as abscissæ we would expect the curve of Fig. 7 to pass through these points which, as you see by Fig. 8, it does.

The order in which the steps have been stated was not quite the same

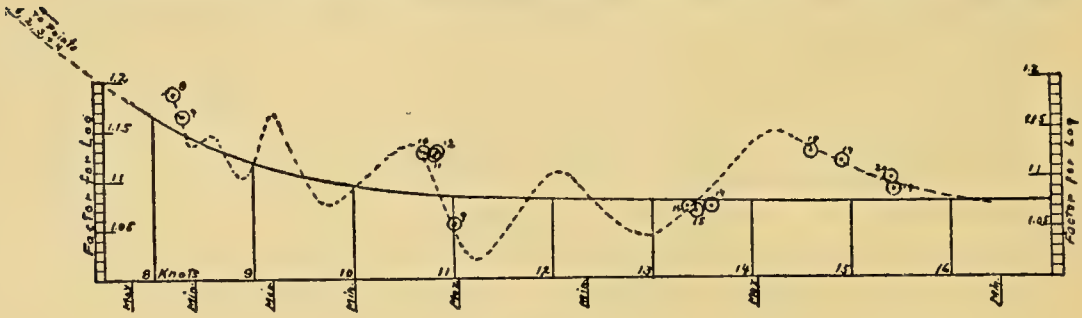


FIG. 8.

as that followed in first working out the results, as no calibration was made of the log in still water and this (curve A–B, Fig. 7) had to be derived by successive approximations but, except for this, the steps were in the order given.

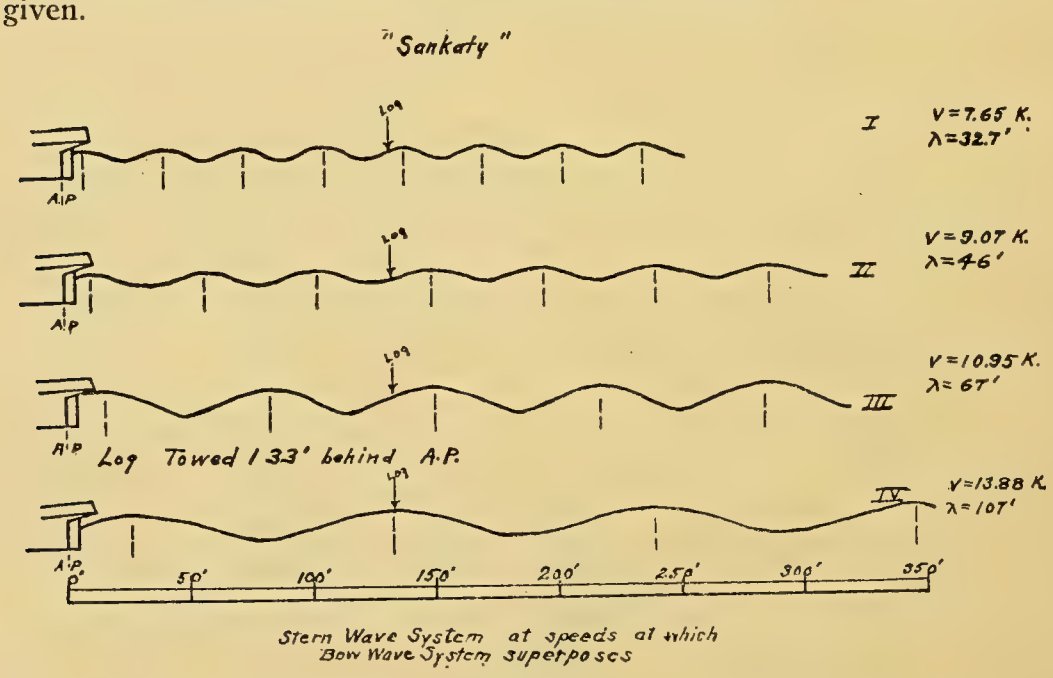


FIG. 9.

The author realized that one experiment hardly constituted proof even though it analyzed so satisfactorily and on the progressive speed trials of the steamer Sankaty, built at the Fore River Company's yard, which trials

were held last spring, the log was again towed. These trials were not quite as satisfactory as those on the Gresham, as there was considerable wind and tide, but the mean curve of speed on R. P. M. is given on Plate 63. The log was towed about 133 feet astern as it was impossible to have it farther astern

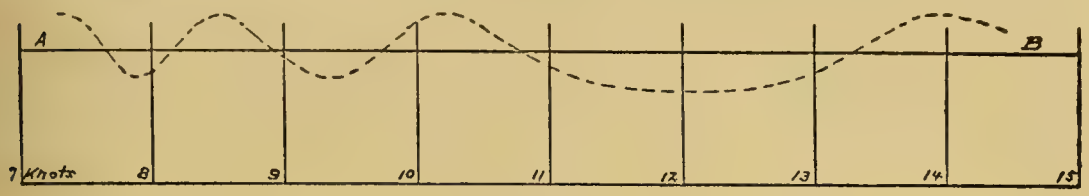


FIG. 10.

without trouble on the turns, and Fig. 9 shows the wave formation at the speeds corresponding to the maxima.

Fig. 10 shows the effect on the log to be expected from the stern system only. Fig. 11 shows the effect of the combined bow and stern systems,

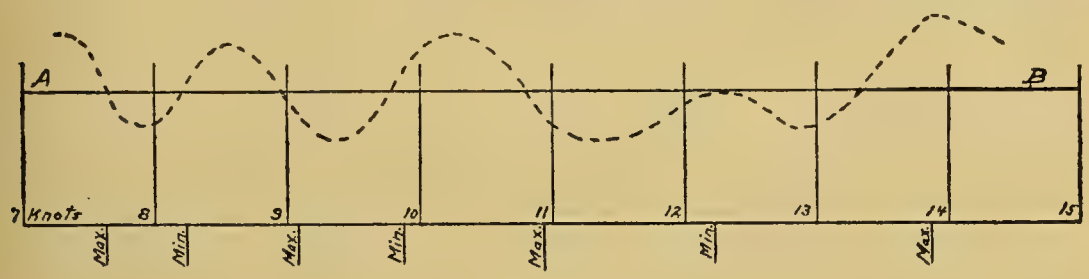


FIG. 11.

Fig. 12 shows this latter plotted about the normal calibration of the log unaffected by waves. Table III gives the results of the trials and Fig. 13 shows the curve derived in Fig. 12 superposed on the experimental points.

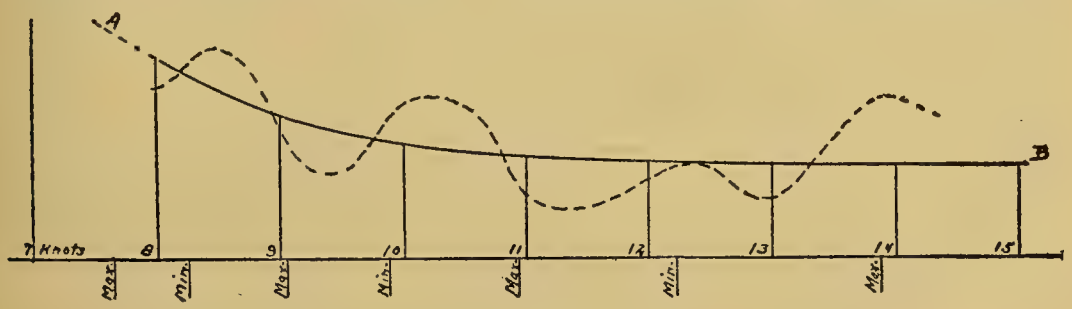


FIG. 12.

Another point is interesting, and that is the amount of the deviation on either side of the still water-line and this is shown by the amplitude of the calibration curve. For the Gresham it varies about six or seven per cent.

TABLE III.—RESULTS OF TRIALS OF SANKATY.* LOG 133 FEET ASTERN.

Run No.	V_{log}	V_{curve}	Ratio $\frac{V_{curve}}{V_{log}}$
4	8.84	9.95	1.126
5	10.47	11.03	1.054
6	10.69	11.03	1.034
7	10.68	11.09	1.037
8	10.47	11.27	1.076
9	11.28	12.12	1.077
10	11.63	12.61	1.084
11	12.41	13.00	1.045
12	12.25	13.21	1.078
13	12.40	13.21	1.066
14	12.12	13.48	1.111
15	12.29	13.70	1.115
16	12.22	13.66	1.117
17	12.25	13.82	1.128
18	12.45	13.98	1.124
19	12.32	13.90	1.133
20	12.32	13.90	1.133

*For Dimensions see Table V.
NOTE—Log not Put out till Run No. 4.

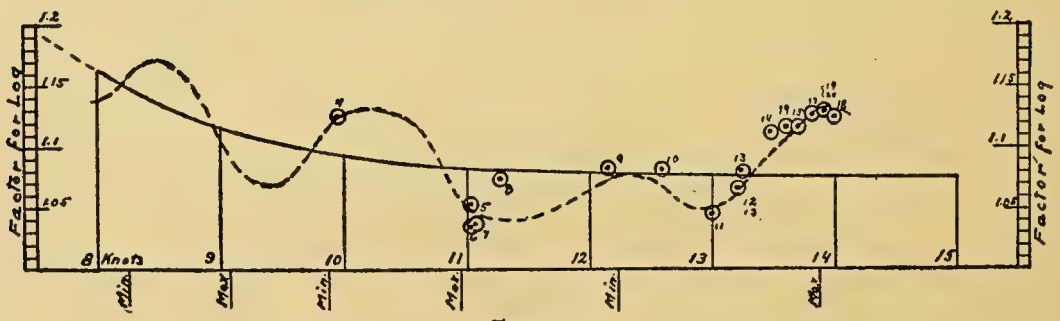


FIG. 13.

alternately under and over, and for the Sankaty about the same. As this is undoubtedly a function of the speed of a particle in a wave crest or hollow it is interesting to note that the trochoidal wave has a speed of particle of—

$$v = \frac{\pi H}{\lambda} c$$

where—

H = wave height in feet.
c = speed of wave crest in feet per second.
λ = wave length in feet.
v = speed of particle in feet per second.

and if we encountered waves whose ratio of length to height was about 40, then—

$$v = \frac{\pi c}{40} = 0.0785\, c$$

or about 8 per cent. of the speed of the wave crest. A log towed at the surface of such a wave would vary that amount above and below the normal according as it was on a crest or hollow, and less as its immersion increased.

The results of these trials show definitely: (1) That any taffrail log is seriously affected by the wave system carried along by the ship. (2) That in order to be available for measurement of distances at different speeds it must be calibrated by obtaining many points at closely adjacent speeds, and in some manner that takes account of the wave action. (3) The length of the log line must be unchanged throughout calibration and subsequent running; and (4) that a taffrail log as a close measurer of speeds is a questionable instrument. We occasionally find captains at sea who have faith in their logs and who obtain excellent results from them after they have rated them, and this may be quite possible if the vessel sails always at the same speed and the log is towed from a constant length log line, but if a log which is correctly rated for one ship be taken into another ship which has a different length or speed it will usually be far from correct.

TABLE IV.—U. S. R. C. GRESHAM.

Dimensions of Hull, Engines, and Propeller.

Length over all	205 ft., 6 in.
Length between perpendiculars	188 ft., 0 in.
Moulded beam	32 ft., 0 in.
Maximum beam	32 ft., 1½ in.
Mean draft on trial	12 ft., 0 in.
Displacement at trial draft	1,024 tons.
Wetted surface	7,330 sq. ft.
Diameter high-pressure cylinder	25 in.
Diameter intermediate cylinder	37½ in.

Diameter low-pressure cylinder	$56\frac{1}{4}$ in.
Stroke, all pistons	30 in.
Diameter of propeller	10 ft., 0 in.
Pitch of propeller	12 ft., 6 in.

TABLE V.—STEAMER SANKATY.

Principal Dimensions.

Length over all	195 ft., 0 in.
Length B. P. (A. P. at rudder post)	188 ft., 0 in.
Beam moulded at 8 ft. 0 in., normal water-line.	31 ft., 6 in.
Beam over guards	37 ft., 0 in.
Depth, moulded	12 ft., 6 in.
Draft, mean moulded	8 ft., 0 in.
Displacement to 8 ft., 0 in. normal water-line.	688 tons, S.W.
Wetted surface	5,700 sq. ft.

DISCUSSION.

VICE-PRESIDENT MCFARLAND:—Gentlemen, you have heard the paper on "The Effect of Waves Upon a Taffrail Log," by Prof. Harold A. Everett. Discussion is now in order.

PROFESSOR WM. HOVGAARD, *Member:*—This paper has the rare merit of being of direct practical influence, and will no doubt prove of importance to navigators and shipbuilders. I find nothing in it to criticise, but will only make a few additional remarks.

The magnitude of the deviation of the log factor on either side of its still-water value is a function of the height of the waves, as stated in the paper. Now, this height must depend upon the size and form of the ship, and will presumably increase with the depth and fullness. For large ships of full form, offering great wave resistance, we may therefore expect to find the greatest fluctuations in the log factor.

There is another source of error in the log of similar character to the one here discussed, viz., due to the ordinary sea waves. Suppose first the sea runs in the same direction and with the same speed as the ship, we shall then have, theoretically, a constant reinforcement or weakening of the wave system produced by the ship, with a corresponding influence on the log factor. The same will be the case even

if the line of advance of the sea forms an angle θ with the course of the ship, provided the speed of the waves is (Sec. θ) times the speed of the ship, and provided θ is smaller than 90 degrees. When the sea is forward of the beam, no permanent influence on the log seems possible, since the waves will in that case always be passing.

In reality the waves of the sea are irregular, and their speed will rarely conform exactly to the above rule. We may, therefore, expect that this source of error will be negligble in general, but cases may arise where it ought to be taken into account.

MR. CHARLES P. WETHERBEE, *Member:*—I wish to say it seems to me as if there might be some other factors also, that affect the accuracy of the log, such as the wake of the propeller and the immersion of the log. Of course the immersion depends on its distance from the vessel. As near as I can understand from Professor Everett's paper his conclusion is that the log is unreliable, but that it can be standardized, so that no matter what the errors depend upon they can be taken into account in the standardization.

The general opinion among seagoing people seems to be that the revolutions of the screws are really a more accurate gauge of the speed of a ship than the log, and while the revolutions of the screws vary under different weather conditions, they do not vary as much as the variation of the log.

VICE-PRESIDENT MCFARLAND:—Apparently there is no further discussion on this paper. As there has been no criticism, do you care to say anything further, Professor Everett?

PROFESSOR EVERETT:—With reference to Professor Hovgaard's remarks, I think that is an interesting point which he brought out, but, of course, it applies to only one condition which occurs, and that but rarely, that is, when the waves of the sea are of the same identical speed as the waves of the ship.

With regard to Mr. Wetherbee's point, the race may affect the log, but it is impossible to separate it, and it would seem to be in the nature of a constant variant. The depth of immersion must have an influence on the amount the log overruns or underruns, but at the same time I have said in my paper that the log must be calibrated under the identical conditions under which it is to be used, and if the conditions with reference to length of log line and speed are the same, the chances are the log immersion is the same, so that the question of depth of immersion is taken care of in the calibration plot. I am not advocating the calibration plot for the log, to permit it being used as an accurate measurer of speed or distance, because I question if it could be derived to the accuracy desired, but my principal point is that the log is very unreliable unless calibrated as outlined.

VICE-PRESIDENT MCFARLAND:—With which we all agree.

We extend the thanks of the Society to Professor Everett for his interesting

paper. We will now take up the paper on "The Raising of the Dry-Dock Dewey," by Naval Constructor L. S. Adams, Member. I understand Constructor Adams is not here, and our good friend, the Secretary, will give a brief statement of the paper. I went over this paper myself, when it was submitted to the Publication Committee, and found that it is a most interesting paper, and that it will repay very careful reading, but our time is so limited that we can only pay it the respect of giving it a very brief notice this afternoon.

SECRETARY DANIEL H. COX:—I think it is unfortunate, not only that Mr. Adams is not here himself, but that the time at our disposal is so short, because I think the paper is exceedingly interesting and well worthy of careful consideration, particularly in view of the historical voyage that the Dewey made over the sea.

The Secretary presented the paper.

THE RAISING OF THE DRY-DOCK DEWEY.

By Naval Constructor L. S. Adams, U. S. N., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

The raising of the dry-dock Dewey which sank at Olongapo, Subig Bay, Philippine Islands, in May, 1910, was a wrecking operation somewhat out of the ordinary, and it is believed that a description of the methods employed and the difficulties and problems encountered in the work of raising will be of general interest to the Society.

Although the dock has been described at length in several technical publications, a brief general description of the dock, and especially of its flooding and draining piping, will help to an intelligent understanding of the work of raising.

Plate 64 shows a general outline plan and elevation.

Plate 65 shows the arrangement of water tanks and their capacities, and the arrangement of the pumping and flooding piping, in the forward half of the dock. The after half is generally similar in arrangement to the forward half, except that it contains only one centrifugal pump.

Plate 66 shows a cross-sectional view with some details of framing and machinery.

Plate 67 shows the general arrangement of machinery on port side.

Plate 68 shows the general arrangement of machinery on starboard side.

Plate 69 shows a section on center line of pontoons and elevation of inside of port side wall.

Plate 70 shows general arrangement of pontoon and side wall decks.

The Dewey is a steel, floating, self-docking dry-dock, with a lifting capacity of about 20,000 tons, a length over-all of 501 feet, a clear width inside of the side walls of 100 feet; and it can be sunk so as to have 37 feet of water over 4-foot blocks and still have 4 feet of freeboard. The self-docking feature was secured by building it in 3 sections, securely bolted together to form one structure when used as a dock, but entirely separate when self-docking. The main or middle section contains all of the boilers and main steam pumps, and other machinery. The machinery is all located on the port side, which is the side that sank, except one auxiliary boiler, some machine tools, etc., which are on the starboard side. The machinery is all

located on what is called the machinery deck, which is 16 feet 6 inches below the top deck of the side wall. The total displacement of the dock in the light condition, without a vessel in it, is about 11,000 tons. The central pontoon is divided into 14, and each end pontoon is divided into 5 main water-tight compartments. These main compartments are still further sub-divided by water-tight bulkheads, so that there are 32 water-tight compartments in the main pontoon and 18 in each end pontoon, making 68 in all. The general arrangement of these bulkheads in the forward half of the dock is shown on Plate 65. These compartments have a depth of 18 feet, 6 inches below the floor of the dock.

Combined flooding and draining pipes with quick-acting gate valves lead from each of these 68 compartments to a main drain and flooding pipe running along in the bottom of the port side of the dock. The valves in each main compartment are all operated by one lever in the valve house, which is located on the upper deck of the port-side wall amidship. The pumping machinery consists of three 24-inch horizontal centrifugal pumps and three Babcock & Wilcox boilers. The pump engines are on the machinery deck, the pumps themselves being in the bottom of the dock. Each of these pumps has a capacity of discharge of about 35 tons of water per minute. The flooding of the ballast compartments is accomplished from sea valves into the one system of piping which is used for both pumping and flooding. The main line of piping is fitted with a flexible connection where it passes from the main or central pontoon to each end pontoon. There are stop valves on either side of these connections and also other stop valves located in appropriate places in the main line of piping. All sea and stop valves are operated by means of hand wheels on the top of the side wall. Each ballast compartment is fitted with a vent pipe leading up to the top of the side wall. These vent pipes in some cases necessarily pass through several other compartments before reaching the top of the side wall and the atmosphere. All the ballast compartments are in the bottom part of the dock below the dock floor with the exception of compartments Nos. 1 and 7, which extend up into the side walls, their tops being formed by the machinery decks on each side. These compartments Nos. 1 and 7 are by far the largest of all the ballast compartments.

In May, 1910, the blocks of the dock had been prepared for two torpedo boat destroyers, which it was intended to dock early in the morning of May 24. On the afternoon of May 23, the dock was lowered to a depth of 26 feet over the keel blocks, which left a freeboard of 15 feet on the side walls. This lowering of the dock a night in advance was in accordance with the usual custom so as to have the dock in readiness and avoid delay.

About 1 A. M., on May 24, 1910, the valve man on watch noticed that the dock had taken a slight list to port. He accordingly corrected this list by admitting water which lowered the dock to a depth of 27 feet over the keel blocks. Shortly before 4 A. M., he noticed that the dock had again listed to port, and that the port side seemed to be rapidly going down. He called the dock-master, but before anything could be done, the port side was completely under. This was about 4.30 A. M. The starboard side also sank somewhat and was slowly filling with water. The dock's position at 10.20 A. M., on May 24, 1910, is shown on Fig. 1, Plate 71. No cause was known then for the sinking of the dock; in fact the cause was not definitely ascertained until the dock had been completely raised. It was known that much of the drainage piping had many small holes in it. Repairs had been made from time to time, but no complete overhauling had been made, it being the intention to give the dock and all its piping a complete overhauling at its next self-docking, which was scheduled to take place in about seven months. It was not believed that any small holes that there might be in the drainage piping could possibly be sufficient to cause the sinking of the dock or to even appreciably interfere with its operation. It was thought possible that one of the main drainpipe connections between the central and end pontoons might have given way, thereby flooding one of the large compartments, No. 7, which would have been sufficient to sink the dock. Also one of the sea valves might possibly have given way. This also would have been sufficient to sink the dock. But it was soon ascertained that neither of these things had happened, and that there was no material damage to the dock structure. This was demonstrated to be the fact by opening the various compartments on the sunken side to communication with compartments on the starboard side where the action of the water in the starboard compartments could be observed. This will be described a little more fully later on in this paper. The work of raising the dock was therefore considerably complicated by the fact that the cause of its sinking was not known, and a great deal of investigation work was necessary in order to eliminate certain possible causes and to determine as far as possible the general condition of the structure, piping, etc. It may be well to state, in view of many misleading reports published at the time the dock sank, that there were no open valves, and no open manholes, that were the cause of the sinking of the dock.

The work of raising the dock will now be taken up. Where the dock lay the depth of water over the bottom was about 65 feet at the inshore or forward end of the dock, and about 70 feet at the after end. The character of the bottom was soft mud to a depth of about 3 feet, and under that com-

paratively hard sand. The top deck of the side walls on the port side was about 6 feet under water at the forward end, and about 16 feet under water at the after end. These figures should be increased about 2 feet for high tide and decreased 2 feet for low tide. The outer edge of the bottom of the port side had sunk into the mud to a depth of about 10 feet at the outer end, and kept sinking farther into the mud until it was eventually about 18 feet in the mud, before the dock was raised. On first sinking the starboard side remained afloat, but it was gradually filling with water. Work was immediately begun to save the starboard side. All openings in the top deck were closed water-tight, and five pumps were mounted below in the machinery spaces to pump water from No. 1 tanks up through the manholes. These pumps were all small plunger pumps being in size 3 inches to 6 inches suction. Steam for these pumps was furnished from the dock's auxiliary boiler located in the starboard machinery space and also from a small tug.

Fig. 2, Plate 71, shows the position of the dock on May 26, 1910, two days after sinking. The starboard side had gone down so that its outer end was about 3 feet under water. By this time, however, the pumps had been mounted and were in operation and the starboard side was saved from further sinking and was raised until it was about 2 feet out of the water at the outer end, and 12 feet out at the inner end. These pumps had to be kept going day and night during the entire time until the dock was finally raised. There was always slow leakage to take care of.

The alternative plans determined upon for attempting to raise the dock were as follows:

1. By introducing compressed air into bottom tanks Nos. 4, 6, 9, 10, 11 and 12 on the port side. This seemed at first sight the simplest and quickest method of raising the dock. Tank No. 7 was not to be utilized for the reason that the top of this tank was formed by the machinery deck which had many small openings in it, such as deck drains, steam drains, etc., which would have made the retention of air very difficult, and the other tanks had more than enough buoyancy to lift the sunken side.

2. By making water-tight the compartment in which the forward centrifugal pump for operating the dock was located; then clearing this compartment of water and operating the dock's own pump by steam furnished from the tug Wompatuck. Before doing this, however, it was decided to attempt to run this pump under water by means of compressed air. For clearing this compartment of water, a steel cofferdam was built and fitted over the skylight coaming and a 10-inch centrifugal pump was mounted on a platform on the outside of the cofferdam and its suction taken down into the compartment below through a small hatch. This pump had a lift of about 30 feet to entirely

clear the compartment of water. In addition to this, a duplex pump with 6 inches suction was mounted on the outside of the cofferdam with its suction running down inside. This was in order to keep the water down in the compartment after it had been taken out by the centrifugal pump. The end bulkheads in this compartment were nonwater-tight and were very inadequately stiffened. Extensive shoring was necessary to provide against their collapse and considerable work was involved in making them water-tight.

3. By making the whole top and bottom decks and the side walls of the machinery space on the sunken side water-tight; then clearing this whole space of water, which would provide nearly 3,000 tons buoyancy (about 5,500 being necessary to lift the sunken side); and then by utilizing the dock's own pump to raise her or, in case of the failure of this, by mounting pumps below and pumping water out of the No. 7 compartments. This was the surest method, but also the longest and the most costly.

The second and third of these methods were based on there being no serious damage to the dock's structure and no large opening to the sea. This was conclusively demonstrated to be the fact by opening various other compartments into the No. 1 compartments on the starboard side, and then observing the action of the water in the No. 1 tanks. The opening of the other compartments into the No. 1 compartments was accomplished through the dock's pumping and drainage system, the valves in the valve house being operated by divers. This showed general leakage but not enough for any large opening to the sea. Furthermore, such examination as could be made of the dock by divers did not disclose any open manhole nor damage to the dock's structure. The sea valves and the connections of the drainage pipes between the middle and end pontoons were, however, inaccessible by divers and could not be examined.

It was necessary that the raising of the dock be accomplished as soon as possible owing to the approaching typhoon season which was due in about one month. Therefore preparations for the three methods of raising the dock were begun at once and at the same time. For the first method, power floats containing air compressors and boilers were fitted up at Cavite and sent to Olongapo. There were two floats containing each a compressor of from 400 to 500 cubic feet of free air per minute capacity compressed to 100 pounds, and one other float containing five small torpedo air-compressors obtained from the torpedo testing room. Twenty manhole covers were manufactured, each containing a $1\frac{1}{2}$-inch air connection with cut-off valve for introducing compressed air, and a 3-inch pipe running through the manhole and extending down to a depth sufficient to reach within one foot of the bottom of the tanks. The latter pipes were for the ejection of the water and

were also fitted with cut-out valves at the tops. These manhole covers were placed in position by divers. It was considered hopeless to attempt to introduce compressed air through the vent pipes particularly in the end pontoons as they were badly corroded and leaky, and furthermore this method was considered somewhat hazardous due to the fact that the flow of water from the tanks could not have been accurately determined as it would have been through the drainage system, and there would have been danger of damaging the tanks and bulkheads from excessive pressure. The method of introducing compressed air through manhole covers enabled the divers at all times to determine with absolute accuracy the action of the air and water, as the water could be plainly felt coming out the ejection pipes.

For the first plan of raising the dock, the 20 manhole covers were installed and all vent pipes plugged tight as far as possible. A large amount of work was involved in doing this as in some cases whole sections of corroded pipe had to be removed or renewed by divers. In all, about 1,100 feet of piping were renewed. These pipes could not be made completely tight owing to the fact that some were leaky where they passed through tanks Nos. 8, 12, and the self-docking tanks, which places were inaccessible to the divers. However, they were made sufficiently tight to retain compressed air without excessive leakage.

Fig. 1, Plate 72, shows the starboard side under control and the floats, etc., at work. Before introducing compressed air a hose from the accumulator was led to the floor of the dock. The pressure in this hose was increased until the air just came out at the end and such pressure was noted. A number of hose connections were then made to the various manhole covers and air was introduced at a pressure of 2 pounds in excess of the pressure already determined of the head of water outside. These connections were all to tanks on the low side, but it was found that the air went at once to the tanks on the high side. This was probably due in part to leakage through the vent pipes in the tops of the tanks, but it was mainly due to the fact that the tank bulkheads proved to be non water-tight at the tops, allowing air to pass freely from one tank to another. In one case the air went through 5 bulkheads, one of them being the center-line bulkhead which had no pipes whatever running through it. In all cases the air forced the water out of the tanks on the high side first, through the drain piping and closed valves, lifting the high side only. This non water-tightness of bulkheads at the tops was not known before attempting to introduce the compressed air, there being nothing in the plans and specifications to show it. This method of lifting the dock was therefore proved to be impracticable and even dangerous from the excessive pressure that would have been produced in the tanks on

the high side when that side had been raised out of the water, and the outside head lessened. Consequently it was abandoned.

It was then attempted to operate the dock's forward centrifugal pump under water by means of compressed air, the exhaust pipe having been run above the water-line from the outboard connection through the side wall. The pump was started by this means, but only 30 pounds pressure could be obtained with the air plant available, and this was not sufficient to eject any water against the outside head. In fact a minimum of 80 pounds pressure is required under normal conditions to operate this pump. This method was also abandoned. Subsequent events showed that it would have been impracticable even had sufficient air capacity been available.

The second method of attempting to raise the dock by steam on its own pump was then taken up. After many annoying difficulties, the pump compartment bulkheads were finally made water-tight, the bulkheads sufficiently strengthened and the compartment cleared of all but about 2 feet of water. About 3 P. M. on June 14, 1910, the dock's own pump was gotten in operation by steam from the Wompatuck. The discharge had already been cleared by divers digging away the 14 feet of mud and hard sand in which it had sunk.

Fig. 2, Plate 72, shows the first result of operating the dock's own pump. The starboard side came up first, the pump taking water from the tanks in that side before it would take any water whatever from the tanks in the low side. The vent pipes from the tanks in the low side had been fitted with hose connections to the atmosphere and there was no indication of any air going into them, which would have been the case had the pump been taking water from them. This was due chiefly to the fact that all compartment valves are of the quick-opening type, many being operated by one lever, which prevents them from being anything but approximately tight. The leakage was, however, far greater than had been anticipated. Furthermore, these valves occasionally break in use and no doubt some were broken. Also some of the drainage piping was leaky through small holes in it and this also allowed water to pass from some of the compartments to others. No matter which valves were open or closed, the pump took water from the high tanks before removing any from the low tanks. This action was wholly unlooked for. This operation was then stopped temporarily. The No. 1 tanks on the high side were then completey filled with water and the vents plugged. At about 9.30 P. M. the dock's pump was again started with the same result as before. The starboard side came up first, and at about 5 A. M. the next morning it had been raised to about 14 feet on the draft board at the forward end, and 24 feet on the draft board at the after end. (These drafts

are over the keel blocks.) It was then noticed that the forward end of the sunken side was beginning to come up very slowly, and the operation was continued until the dock reached the position shown in Figs. 1 and 2, Plate 73, and Figs. 1 and 2, Plate 74. This position was reached about 9.30 A. M. At this time the whole forward end was coming up rapidly. The starboard after corner was going down, and the port after corner was coming up very slowly. At this time the pump was drawing water from tanks Nos. 4, 6, and 7 forward, but practically none from Nos. 4, 6, and 7 aft. Both end pontoons were completely shut off by the stop valves. Both No. 1 tanks on the high side were practically empty of water. The whole forward end pontoon was completely full of water. It will be noted from the figures that the water in the forward end pontoon was beginning to be lifted above the surface. The weight of the end pontoon together with the water in it was in the neighborhood of 7,000 tons, and it was considered dangerous to continue this operation further. To have done so would surely have resulted in straining the dock and probably in tearing off the end pontoon. At the time the operation was stopped, no deflection of the dock structure could be noticed and there was no sign of giving way of the bolts securing the end pontoon to the side walls of the center pontoon. Furthermore, this operation alone would not have raised the dock, for the reason that as soon as the forward compartments were emptied, the pump suction would have drawn air, after which the suction to the after tanks would have been lost and the after end could not have been lifted by that means. It was then planned to introduce compressed air in the after pontoon, in order to lift the after end of the dock. It was, however, doubtful whether the dock could be satisfactorily raised in this manner as this also would have lifted the high side first, and it was feared that severe strains might have been put on the dock due to the fact that the port after corner would have served as a pivot while the rest of the dock was raising first. However, it was decided to attempt this with the idea of discontinuing it if the action of the dock was not satisfactory. For this purpose the dock's pump had to be kept going from time to time, in order to keep the low side from sinking through leakage. About 4.30 P. M. it was found that the dock's own pump was in such bad condition due to having been working in mud and salt water and at an excessive inclination and also due to the breaking of the oiling gear, that it needed overhauling. It was accordingly stopped for repairs which were not completed until about midnight, at which time the port side was just sinking below the surface. This method of lifting the dock was then abandoned, it being considered a dangerous one even with the assistance of compressed air, and the action of the compressed air being very uncertain.

The third method of raising the dock, outlined above, and for which preparations had been in progress, was then begun. The whole sunken side was made water-tight, the bulk of the work being on the top deck of the side walls, which had a great many nonwater-tight openings in it. Five cofferdams were used as follows:

The first cofferdam from forward was the one previously fitted for obtaining access to the dock's own forward pump. The 10-inch centrifugal pump and the 6-inch pump were retained on this cofferdam for use in pumping out the whole machinery space after opening up the end bulkheads of the pump compartment that had previously been made water-tight.

The second was a large one about 5 feet 6 inches by 7 feet 6 inches and was mounted on the dynamo-room skylight coaming. This cofferdam was for the purpose of lowering pumps through it, to be mounted on the deck of the machinery space below in order to keep the water down after it had been removed and the upper pumps having lost suction, and also in order to install pumps (if found necessary) for removing the water from the No. 7 compartments. No pumps were mounted on this cofferdam.

The third cofferdam was mounted on the skylight coaming over the dock's middle centrifugal pump. There was mounted on the outside a plunger pump with a 6-inch suction, taken from the Piscataqua.

The fourth cofferdam was built over the door to the valve house and was for providing access to the interior of this house for the operation of the valves. All windows and ventilators in this house had to be made tight and the house had to be very heavily shored inside. It was built of thin plating, non water-tight, and it was necessary to make it water-tight for the reason that the deck inside of it could not be made so where the valve operating gears passed through it.

The fifth cofferdam was mounted on the skylight coaming over the after dock pump and a 12-inch plunger bucket pump was mounted on the outside, the suction pipe going down inside the cofferdam. All these cofferdams were of steel and were shored from the deck of the dock, with the exception of the cofferdam over the valve house door which was of wood. These cofferdams are clearly shown on Figs. 1 and 2, Plate 75, and Figs. 1 and 2, Plate 76, which show the dock after raising. A great deal of diver's work was involved in closing all openings in the top of the sunken side. These were made water-tight as far as practicable and the pumps mounted on the cofferdams were then started. They took the water down about 4 feet below the deck in the forward cofferdam after which the head of water outside was sufficient to make the leakage too great to be taken care of by the pumps. The divers were then sent down to make a complete exami-

nation of the deck and side walls. The leaks could then be easily found, due to the fact that water was running in them and could be plainly felt by the divers. All such leaks were accordingly made water-tight, after which the pumps had no difficulty in removing the water. The 10-inch centrifugal pump mounted on the first cofferdam could alone remove the water. The pump on the after cofferdam did not operate satisfactorily when it had to lift water a greater height than about 16 feet. About 2,000 tons of water were removed from the machinery spaces, the machinery deck being bare of water at the high end and containing about 10 feet of water on it at the low end. After this, the centrifugal pump lost its suction, but the 6-inch duplex pump on the forward cofferdam and the pump from the Piscataqua on the third cofferdam were sufficient to keep the water down but could not remove all of it. A duplex pump with a 6-inch suction and a powerful horizontal pump with an 8-inch suction were then placed below through the second cofferdam and mounted on the side wall stiffeners and on the deck respectively in the dynamo room. These two pumps removed sufficient of the remaining water to clear the dock's own central centrifugal pump for operation. At this time there were only about 600 tons of water remaining in the machinery spaces, the deck being bare to almost the middle of the dock. Steam was then connected to the dock's forward pump and the dock's middle pump through flexible piping from the Wompatuck into the main steam line of the dock which was blanked off just abaft the central pump. It was considered desirable and a safeguard to have two of the dock's own pumps ready for operation, so that the work would not have to be stopped in case one pump should break down. The exhaust piping from the central pump was led up thorugh the cofferdam above it to the atmosphere. In the meantime, while this work was in progress, compressed air was being pumped into the after end pontoon through five manholes on the low side. The pumping of the air was continued for 36 hours, at the expiration of which time the starboard after end had lifted about 3 feet and the port after end about 4 inches. The pumping of the compressed air was then stopped. This was 38 hours before the dock's pump was started for finally lifting the dock. During these 38 hours some of the air escaped through leaky vent pipes, but the amount was small compared to the total quantity introduced. The after end of the dock was therefore almost afloat at the time the dock's own pump was started for raising. By this time the port side of the dock had sunk about 4 feet farther into the mud than it was at the time the dock sank. The floating or lifting of the starboard side always forced the port side farther into the mud so that wood extensions had to be built on two of the coffer-

dams first installed. The dock's central centrifugal pump was started about 2.30 A. M. on June 29, 1910. That night there was a strong wind and a heavy rain. The valves of tanks Nos. 6 and 7 aft were the only ones open at first. All forward tanks were shut off and the stop valve in the main line was closed just abaft the dock's forward centrifugal pump. This stop valve shut off half of compartments 1 and 7 forward and also some smaller intermediate compartments in the central pontoon, as well as the whole forward-end pontoon. After a very few minutes from the time the dock's own pump was started it was noticed that the after end, which was already nearly afloat, was beginning to come up. After about fifteen minutes pumping the whole after end was seen to be coming up rapidly and the forward end of the sunken side was coming up slowly. The starboard forward corner was being forced down. This condition continued until the after end of the sunken side had been raised about 4 feet higher than the forward end of the sunken side. At this time the deck of the after sunken end was just coming out of the water. The forward compartments on the sunken side were then opened to the centrifugal pump, after which the sunken side came up uniformly and there was no further difficulty in having absolute control over the dock. The additional 2,400 tons of buoyancy obtained by clearing the machinery spaces, together with the compressed air in the after pontoon, gave sufficient buoyancy to the sunken side and low end so that it came up before there was any appreciable lifting of the high side, such as had been the case when it was attempted to raise the dock by one of her pumps alone. The dock came up perfectly from the start. It was desired to begin lifting the low end slightly ahead of the high end so as to provide a fairly equal height of water in all the tanks and thus obtain better control over the action of the dock. Furthermore, it was feared that if the dock were to be lifted on an even keel in the fore and aft direction, the sunken side might come up with a jump on breaking away from the mud. This might have been accompanied by disastrous results, such as carrying away the big flexible steam hose or striking some of the power floats or the Wompatuck. By daylight, at about 4.45 A. M., the sunken side was well out of the water and the machinery spaces were opened up for access. Three-quarters of an hour after this, steam was up on the dock's own forward boiler in the sunken side and the Wompatuck was later disconnected and the final completion of the raising was done by steam fron the dock's boiler. By 7 A. M. the floor of the dock was completely clear of water, but the pumping was continued to bring the dock to the light condition which was accomplished about 10.45 A. M.

In clearing the machinery spaces of water on the sunken side, the side

and end walls had to stand a pressure due to a head of water of about 26 feet. It was known that this would give an excessive pressure. Accordingly, as the water was pumped down, the walls were carefully observed, as far as practicable, to determine the deflection. The after end wall and the outer side wall aft on the sunken side buckled in slightly and have a permanent buckle of about 4 inches. This, however, is immaterial and does not affect the efficiency of the dock. It is hardly noticeable except on sighting along the surface. Also, in spite of the shoring, the valve house was badly buckled out of shape, due to the water pressure and had to be rebuilt.

As soon as the dock was raised a careful and complete examination was made of the entire structure and all of its piping and fittings. A number of small new holes were found in the drainage and flooding piping. These could not admit water from the sea except in case one or more of the main sea valves should be open or leaky, so that these holes most likely had no appreciable effect on the sinking of the dock, except to make the listing more rapid. In fact they were hardly sufficient to even materially interfere with its operation and handling. The main sea valves were slightly leaky, but this leakage also was insufficient to cause or even to contribute to the sinking of the dock. The vent pipes from the tanks were, however, found to be badly corroded, in many cases being reduced to a mere shell which had given way, thereby leaving large areas open to the sea. When the dock is up these vent pipes are always above the surface of the water, but when the dock had been lowered to take in the torpedo-boat destroyers, these vent pipes were mostly under water, and water entered them and gradually filled the ballast compartments of the dock which caused its sinking. The reason for its going down so rapidly is believed to be that when it once began to take a list to port the water from the starboard side flowed to the port side through the quick-acting gate valves in the drainage system which are only approximately water-tight, and also through the small holes in the drain piping. This, of course, increased the list of the port side even though not admitting any additional water from the sea.

I think that this article is not complete without making mention of the excellent and efficient work done by the divers. There were at work on the dock about a dozen Filipino divers and six divers who were petty officers on the torpedo boat fleet. These latter were under the charge of Gunner G. D. Samonski, U. S. Navy, himself an experienced and efficient diver. His and their work was in my opinion of an unusually efficient character. These men were at work almost day and night for five weeks. The heavy work of fitting the manhole covers with its long piping had to be done in a depth of water of about 70 feet, and some of this work was in very cramped

and almost inaccessible places. They had to go below on the machinery deck to find and close numerous small openings where they had to pick their way among all sorts of machinery, stanchions, pipes and other obstructions where the work was of a dangerous nature. They renewed or removed about 1,100 feet of 3 and 4-inch vent piping under water. They had to dig out about 14 feet of mud and hard sand to clear the sea valves at a depth of 85 feet below the surface. In no case did any of them wear a diver's suit. The helmet alone was used. This seems to be somewhat unusual, in this part of the world at least where the water is usually too cold and makes the entire suit necessary. But without the suit the diver has more freedom of action and can do better work; only he must always keep his head upright. In this work on the "Dewey" there would probably have been loss of life had divers' suits been worn in some instances. Occasionally when introducing compressed air a pipe would give way and in several instances divers were working on pipes that gave way under the compressed air. This released a large volume of air, upset the diver, and almost upset the boat containing the diver's tenders and apparatus, thereby shutting off the supply of air. With the helmet alone, the diver could easily get out of it and come to the surface. The work of these men fully deserves special commendation and thanks.

DISCUSSION.

Vice-President McFarland:—The paper by Naval Constructor Adams on "The Raising of the Dry-Dock Dewey" is now before you for discussion.

Secretary Daniel H. Cox:—It has occurred to me that it might be interesting to have some comments on the state of affairs disclosed in Naval Constructor Adams' paper from Mr. Donnelly, who has had considerable experience with dry-docks. It is a remarkable thing that a dock, subject to the rigid investigation that this one was, should be allowed to get into the state of affairs that must have existed for it to have sunk as it did.

Mr. William T. Donnelly, *Member:*—I should like to say that I regret very much that Constructor Adams is not here to give us a fuller knowledge of some of the details of the raising of this dock. I regard this as especially a praiseworthy piece of work, and my remarks will have some bearing on that subject.

In contributing to the discussion of this paper, I feel that I must somewhat reverse the order of the subjects as considered by the paper. To me the most important part is the personal achievement of the men who accomplished the work of raising the dock. We, as engineers, can plan and cause construction to be created, but after they are completed and tested they pass out of our charge and care, and in this instance we have an example of a structure requiring about two years for its completion at a cost of approximately $1,500,000, being to all intents and purposes completely lost or rendered practically valueless within a few hours, save for the knowledge and energy of those engineers who happened to be on hand at that particular time, and to them I wish to pay the tribute which I consider due; that is, that the knowledge and ability shown in raising and floating the dry-dock Dewey under the conditions, was as great or greater than that required to design and construct the dock.

To lay out the work for the month's campaign which resulted so satisfactorily, was a stupendous undertaking. The paper deals with only the barest details of the accomplishment. The getting together and connecting up of the pumps with their steam and water piping, the gathering of vessels and floats to provide the necesary power, the building of the cofferdams, and the correlating of all this equipment to get the most out of it in the very short time that the operation continued day and night under high pressure, is a test which tries out men and material, and the successful accomplishment of the work should not pass without its proper recognition by engineers, and I, for one, am glad to have the opportunity to acknowledge the high quality of the work.

The second important feature of this paper, to which I should like to call attention, is the very high appreciation I have for the Bureau of Yards and Docks, and the Bureau of Construction and Repair for the very frank and complete manner in which this information has been presented. My entire engineering experience leads me to believe that it takes the very highest kind of moral courage to allow all the facts to speak for themselves under all circumstances, and I am equally certain that, given this courage, the result will always more than justify the action.

Floating dry-docks are of very great importance, both from a military and commercial point of view, and may be said to be an absolute necessity. The number, however, is very limited relative to ships, and our experimental and recorded knowledge relative to their operation is correspondingly limited. Therefore, the knowledge contained in this paper is of the very greatest importance to those who, like myself, are earnestly studying the problem of their construction.

I should now like to take up some of the matters of information which the paper contains and comment upon them relative to the effect they should have upon the future design and construction of floating dry-docks.

Generally speaking, it would seem that the cause of the sinking of this dock was, first, the corrosion of the air discharge pipes, which being submerged when the dock was lowered, allowed water to enter on the port side, causing the dock to list, and that, as soon as this list was established, the water commenced to flow from the

high side to the low side through the center bulkhead, through deteriorated pipe connections to the various compartments and through leaky valves, and that, as the list increased, the corresponding flow of water also increased very rapidly, resulting in that side of the dock becoming entirely submerged until it rested upon the bottom.

As an indication of the amount of leakage through the center bulkhead, the experience in raising the dock is quite conclusive. It appears that, with a considerable inclination, it was more than could be handled by a 24-inch centrifugal pump. Part of this was through leaky valves and defective piping, but a great portion must have been through defects in the bulkhead itself. The inadequacy of the interior bulkheads was also shown by the fact that it was impossible to raise the dock with compressed air, the air escaping in one case through five bulkheads, one of which was the center bulkhead. Bearing these facts in mind, what are the lessons that we are to learn and the additional precautions that we should take hereafter in designing similar structures?

First, I should like to point out that the dock was provided with pumping machinery only on one side and that, consequently, the center bulkhead was pierced with many pipes, upon the integrity of which and their valves the stability of the structure as a whole was entirely dependent. I should lay down as a positive rule that no openings whatever should be made through the center bulkhead of a floating dry-dock and that every possible precaution should be taken to have this bulkhead absolutely watertight. I would call attention to the fact that it is extremely difficult to make and maintain watertight interior bulkheads, and I should lay down as a second rule that interior bulkheads, as such, should be reduced to the smallest number.

It was quite definitely shown by the experience in raising this dock, that the controlling of the pumping from a central point through piping is extremely difficult.

I might refer to one point of the paper where it says: "No matter which valves were open or closed, the pump took water from the high tanks before removing any from the low tanks."

I would suggest as a third rule for careful consideration, that the subdivision and distribution of pumping units to the different compartments of a floating dry-dock is a much more reliable and desirable method than by pipes and valves.

I would also like to point out that in this floating dry-dock there were no reserve chambers or compartments of a sufficient capacity to provide for the buoyancy of the structure entirely independent from these compartments used in lowering the docks. It would seem that there could be no good reason for this construction, and I would offer as a fourth suggestion that in all large floating dry-docks there should be provided watertight compartments entirely distinct from those used for lowering the dock, of sufficient capacity to carry the dock when lowered, and that these compartments should be provided with separate and distinct pumping machinery kept in working order and available for use whenever the dock is lowered.

There are undoubtedly other suggestions that will occur to other members of the Society, and I trust that they will be heard from.

Regarding commercial floating dry-docks, with which type I am more intimately acquainted, I should perhaps state that they are usually placed in a dredged berth and that while the depth of water is sufficient to lower the dock to take the maximum draught for which it was designed, it is rarely or never deep enough to entirely submerge the dock. This is not, however, universally the case. In some ports, such as New Orleans and Seattle, the depth of water is very much greater than required, and in such localities special precautions must be taken. This is also true of the Port of Prince Rupert, B. C. A paper relative to the dry-dock for this port is to be read at this meeting, in which a novel method of guarding against entire submergence will be referred to.

Vice-President McFarland:—Is there any further discussion? Does any gentleman wish to comment on the paper of Constructor Adams? I am sure, in the absence of the author, you will all wish me to have spread on the minutes of this meeting that this paper was very highly appreciated by the Society.

Naval Constructor Adams (Communicated):—I have read carefully the valuable discussion of Mr. William T. Donnelly, on my paper on the subject of raising the Dry-Dock Dewey, and I wish to submit the following comments and points of additional information:

Mr. Donnelly notes that only the barest details of the various parts of the work were given in the paper. There were in reality a great many annoying difficulties encountered in the course of the work, but their description would have taken up so much space that I deemed it unwise to attempt to cover them in the paper, and I therefore confined the paper only to the main points of the work as a whole which were necessary for a full understanding of the subject.

Mr. Donnelly seems to have inferred from my paper that there was considerable leakage through the bulkheads themselves. As a matter of fact, I think there was little if any leakage through the bulkheads except at the very tops, which I think contributed very little to the flow of water from one side to the other. So far as I know from my experience in handling the dock, and also in raising it, all bulkheads were watertight at the bottoms and sides. I believe that the non-watertightness at the tops was a part of the original construction. Under operating conditions the tops of these bulkheads need not be watertight. It was only in the work of raising that such non-watertightness at the tops proved disadvantageous, as it allowed the compressed air to go from one tank to another all over the dock, and thus prevented raising by compressed air alone. The leakage of water from one tank to another encountered in raising, was in my opinion, practically entirely through leaky or broken valves and corroded piping and much of it is inherent in the quick-opening valves and it cannot be avoided with this arrangement for drainage and pumping. Mr. Donnelly seems also of the opinion that the experience with this dock would make it seem desirable to reduce the number of interior bulkheads. Personally, I am of the opinion that this is not desirable. I think the bulkheads in

the Dewey are very well arranged so that they give a very strong structure and one which is also easily handled and controlled in docking vessels. To reduce the number of bulkheads would reduce the facility of handling and controlling the dock and would also lessen the factor of safety in case of damage to the bottom. In further reference to the supposed leakage through these bulkheads, I might add that, in installing the manhole covers preparatory to the attempt to raise by compressed air, several of the bottom tanks were found to already contain some air, which would not have been the case had there been appreciable leakage through the bulkheads.

In regard to the point brought out by Mr. Donnelly relative to the advisability of distributing the pumping units rather than having the control from a central point through a single drainage system piercing the various bulkheads, I believe it more satisfactory to retain the control from a central point as fitted on the Dewey. This method makes it far easier to handle and control the dock in docking vessels, and I believe that the small advantage to be gained by distributing the pumping units and making the bulkheads tight, which advantage would be manifest only under some few possible conditions of submergence of the whole dock, should be sacrificed for the much greater gain in ease of control under working conditions. The drainage piping of the Dewey was all black iron pipe. It would have been better had this been galvanized, as it would have lasted longer and would not have corroded so readily.

Mr. Donnelly also brings up the point of the advisability of providing reserve compartments of sufficient buoyancy to float the dock irrespective of the ballast or buoyancy compartments used for operating the dock and he suggests that such reserve compartments be provided with their own separate pumping systems. In this connection I understand that, in preparing the design for the Dewey, the question of installing a safety deck low down in each side wall was carefully considered and finally abandoned on the ground that, in case the dock were lowered to take in a vessel, and, should the structure be then damaged above one of these decks, the safety deck would become a positive menace owing to the difficulty of getting the water above it to the pumps below. Personally, I agree with Mr. Donnelly that reserve buoyancy compartments should be provided and that they are very desirable if not positively necessary to insure the safety of the dock. Many things might happen below water which would result in accidental sinking. A valve might become jammed open, pipes might corrode in unexpected or unknown places, one of the flexible drain pipe connections between pontoons might give way, the dock might be struck by a torpedo or by shells from the enemy, it might be accidentally rammed by a vessel in docking, etc., etc.; and damage to one of the large compartments, Nos. 1 or 7, would be an especially serious matter, particularly if the dock were lowered to take in a vessel.

I think the best, and possibly the only really practicable form of reserve buoyancy compartments would be obtained by providing a safety deck low down in each side wall. The machinery decks should also be made completely watertight. Then the spaces above both the safety and the machinery decks should be minutely sub-

divided into many comparatively small watertight compartments, and the bulkheads should not be pierced by doors or other openings. In this manner the dock could be made practically unsinkable (except by almost total destruction) and at a comparatively small additional cost. If these reserve compartments were properly designed to provide a suitable excess in reserve buoyancy, several of them could be laid open to the sea, through damage, without reducing the reserve buoyancy to such an extent as to permit the sinking of the dock; and no drainage system would be necessary for them. I think the comparatively small additional cost of such a construction would be amply justified by the great gain in safety and the insurance against accidental sinking.

In conclusion I wish to state that, on the whole, I think the Dewey a very well designed and efficient dock and I would not advocate any radical changes in future designs except to provide reserve buoyancy compartments as outlined above. There are, of course, some minor points where improvements might be made, but these are not of sufficient importance to be considered here.

The meeting was then adjourned until 10 o'clock, Friday morning.

FRIDAY MORNING, NOVEMBER 17.

President Taylor called the meeting to order at 10.10 o'clock, and said:

THE PRESIDENT:—As you know, gentlemen, we have a great deal to do, and a very short time in which to do it.

Mr. H. McL. Harding has kindly consented to allow his paper to be read first, and I will call for the paper entitled "Cargo Transference at Steamship Terminals," by Mr. H. McL. Harding, Consulting Engineer.

Mr. Harding presented the paper.

CARGO TRANSFERENCE AT STEAMSHIP TERMINALS.

By H. McL. Harding, Esq., Consulting Engineer.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

The purpose of this paper is to indicate the importance of terminals in water transportation, and to show the feasibility of increasing the rapidity of freight movements, of reducing the handling costs, and of increasing the capacity of existing terminals, by the adaptation of improved mechanical methods.

In this is a large field for the activities of naval architects and marine engineers, and the subject will well repay study and investigation.

In the railway world up to the present time, the energies of engineers have been devoted to the engineering problems arising between terminals, such as improving the performance of the locomotive, increasing the durability of the rolling stock and the economical maintenance of tracks and way, while the influence of the terminals on the rapidity and economy of railway transportation, long neglected, has only lately been fully recognized. One example of this awakening is the installation of freight handling machinery at St. Louis, by the Missouri, Kansas & Texas Railway under the direction of Mr. S. B. Fisher, the chief engineer. Here the operation of a $3,000,000 freight terminal depends absolutely on mechanical methods instead of manual labor, and a crate of eggs and the heaviest hogshead of tobacco, a wicker chair and a grand piano are equally well handled.

Similarly the naval architect and the marine engineer have been concerned as to the movements between terminals rather than those at terminals. The design of the ship, the type of engine, the coal consumption and other most important details of marine engineering have occupied their minds and been their chief concern.

Marine engineering should now include the many terminal problems. This would enlarge the day's work with its proper recompense and should be a part of the curriculum in the education of the naval engineer.

This paper with its figures and data will be confined to miscellaneous package freight excluding bulk freight, and mainly refers to export, import and coastwise traffic. Unavoidable necessity is now compelling the substitution of machinery for the armies of men employed in this class of freight

movements. The normal proportional increase of general freight is more than two and one-half times that of the population, and the proportion of package freight increase is at least twice that of general freight. This is largely the result of converting raw material into manufactured products at its place of origin and the great increase of manufacturing.

In water transportation in the United States for large tonnage, the terminal costs are greater than the carriage costs. As an example, the cost, including carriage and terminal expense, to the transportation company per ton of freight for nearly 2,000 miles was $1.56, of which the labor terminal costs at both ends of the route were 79 cents.

The estimated cost of the carriage of one ton of freight on the Erie Barge Canal in a 2,000-ton barge between a steamship pier at Buffalo and a steamship pier at New York is 26 cents, while both terminal costs by manual labor will be more than 30 cents.

The rental and fixed overhead terminal costs for a large tonnage at the port of New York are in certain cases between 25 and 35 cents a ton. This is exclusive of manual labor. It is necessary to give this large variant due to the influence of the volume of tonnage upon this cost. Similar overhead charges at a number of large railway terminals average about 28 cents per ton not including the labor expense of trucking.

It is desired in this paper to cover concisely:

First.—The present movements at terminals of miscellaneous freight both outbound and inbound, with special reference to the different classes of package freight.

Second.—The usual methods of handling cargoes to and from ships, lighters, drays and cars.

Third.—Description of the different kinds of freight-transferring machinery with the details of the mechanism and comparative costs.

Fourth.—Conditions to be fulfilled by any machinery and the latest adaptation of different kinds of standard machinery to the freight movements with a statement of capacity and rapidity of loading and discharging.

Fifth.—Installation cost of such machinery, including interest and amortization, the costs of operation with maintenance and comparison with manual costs.

Sixth.—Summary and deductions.

The following suggestions can be only general and are subject to many exceptions.

A complete terminal adjusted to the space available should consist of ample sized piers, proportioned to the volume of freight, bulkheads or quays, transshipment sheds and warehouses all adapted to the kind and conditions of

traffic, modern mechanical appliances for freight transference, and a coordination between the rail and water terminal with due regard to the land and water approaches. Consideration should be given to future development and extensions.

There should be a width in the slips between jutting piers at least four times the width of the largest steamships there to be regularly berthed, and when possible, the width of the pier should be one fifth to one fourth the length.

The best practice, in the construction of the piers, and in the design of the sheds and warehouses is of the greatest interest, but in the thirty minutes allotted to this paper cannot be described, except in so far as they affect the transference of freight by modern machinery.

The suggestions are made from the standpoint of long-distance mechanical freight handling, and the practice differs from the usual methods where manual labor has been dominant.

Where provision for freight and not passengers is of the chief importance, the sheds, being for transshipment only and temporary storage, should preferably be of one story, 35 or more feet in height beneath the girders and with galleries for passengers.

Where there is baggage to be examined a location can be provided in the bulkhead sheds which may be of two stories. Most of the sheds abroad, even where hand or surface trucking is the custom, are of one story.

The chief reason for two-story sheds, except for passengers, is to obtain greater capacity. One story 35 feet in height will give a greater capacity than two stories each of 18 feet when the former is equipped with correctly designed hoisting and conveying machinery, thereby rendering high tiering feasible and using vertical rather than horizontal space, that is, not spreading the separate consignments over so much floor space.

Tiering by machinery costs no more than to place the goods upon the floor, and one story obviates the necessity of additional hoisting or lowering mechanism between the floors such as elevators or ramps. There would be one installation of hoisting and conveying machinery instead of two, as well as an equal or greater storage capacity. The pier superintendent can exercise better supervision over one story than over two, the result being less loss and breakage.

Where there are two stories of the usual height, and of a width of 150 feet, the lower story is often not well lighted, damp and not properly ventilated.

The walls of the freight sheds can be advantageously placed either 5 or else about 20 feet from the edge of the pier. This is contrary to the pre-

vailing practice at European ports, as there the walls are generally set back between 30 and 40 feet.

This arrangement is a disputed question and open to argument, as it was only after long study that this seemed best for package freight handling, but there are many exceptions. The suggestions given are for general rules and not for the exceptions.

The advice of the engineer and architect should be obtained, and their decision should only be given after a complete investigation of the freight handling and other conditions.

Shed Location.—Where it seems best to place the wall back from the edge of the pier, there should be a cantilever roof extending to the edge of the pier to protect the workmen and freight, and to permit the work of transference to proceed under all conditions of weather.

This cantilever roof is not possible with the standard traveling gantry crane with the high swinging jib.

Among the reasons for the walls of the sheds being placed within a few feet of the edge of jutting piers, are the greater storage capacity under cover, the protection of the cargo during transit between the vessel and shore, and the possibility, sometimes desired, of swinging the drafts into the sheds by the ship's winch.

One of the reasons for the broad open space of from 35 to 40 feet at foreign seaports between the edge of the pier and the shed, was that the crane jibs could not otherwise be easily operated while serving one or more lines of railway tracks, dray space and the adjacent shed platform.

Cars on Piers.—In respect to the transferring of miscellaneous package freight between vessels and cars, which must be assorted according to consignments, there seems to be doubt as to the advantage in having cars between vessels and sheds as is the custom with the usual traveling gantry.

It may be that in one draft from the hold there may be consignments which must be distributed to cars located upon the tracks at a considerable distance from each other. The gantry must then lower the load upon the pier, where, after it has been assorted, it must be distributed by trucking to the different cars.

Where, however, the cargo consists of few consignments and with bulk freight, so that cars can be loaded directly from the vessel without regard to marks, then there is economy and rapidity in loading directly from the vessel to the cars.

Miscellaneous outward freight can seldom be taken directly from the car opposite a hatch and stowed in the vessel. The stevedore being responsible for breakage and damage insists upon stowing the cargo in the ship

with due regard to the character of the freight. In some cases the freight must be placed in the vessel according to the order of the ports of call.

It is not considered advisable to depress railway tracks or driveways even when tracks are permitted on piers, as this hinders the freight movements directly across the pier.

Disputed Questions.—The suggestions presented as to the number of stories and the location of the sheds, and the railroad tracks upon the piers, are because these are important and disputed questions. They are, however, readily solved from the standpoint of the installation of correctly designed transferring machinery. Where possible it is a good rule to make the bulkhead sheds one-half the width of the pier and not an arbitrary 50 feet.

Warehouses.—At the rear of the sheds with a space between, should be the warehouses, generally for long storage, of as many stories as may be required, but each story should not be less than 20 feet or more in height.

Freight Movements.—With reference to the movements of outbound freight, it is received at the piers from cars, drays or lighters, or from other steamships for reshipment. When the freight is received from large shippers or other transportation companies it is not weighed or measured, but the weights given are generally accepted as correct; otherwise it is weighed or measured. Coastwise freight is weighed, but export freight is measured unless it is of heavy weight per cubic foot.

The dray freight, as it is delivered, is placed along the pier side, inside the shed, in such a way that it can be most advantageously selected by the stevedore for stowage when the ship is ready. Freight must be stowed in the vessel according to its weight and nature and liability to injury. If the ship be not ready the freight is tiered on the pier, the height being regulated by the amount of freight and the floor space, but tiering by hand higher than six to eight feet is avoided.

When the ship is ready to be loaded, the freight is trucked, generally by manual labor, within reach of the ship's winch or the jib of the gantry crane, or trucked through the side ports of the vessel if of the coastwise type. Upon a certain pier in New York for outbound freight the average distance which the freight was trucked was 550 feet with an average load of 184 pounds and at an average speed of 110 feet per minute which included the delays of loading and unloading the trucks.

The freight, as it is received, is inspected as to condition, and the number and description of packages compared with the bill of lading. At this pier, the outward dray freight amounted to 800 tons daily, which with 200 tons of freight from lighters alongside the pier equalled 1,000 tons daily which must be trucked. There were also 1,000 tons of off-shore freight, making a daily total of 2,000 tons.

Lighterage-Freight Movements.—The lighterage freight may be divided into two classes, that which passes upon the pier from the lighter and then to the ship either directly or after temporary storage, and that freight which passes to the ship from the lighter located alongside the vessel on the off-shore side. On account of the slowness in unloading off-shore lighters, there is generally much congestion in the slips.

From the above, it will be seen that berthing facilities must be provided for lighters alongside the piers, the best location being on the opposite side of the pier from the steamships, or if there be room, upon the same side. Where piers are 350 or more feet in width, as at many European ports, with two sheds, a space between and railroad cars, it would be difficult to truck lighterage freight as is being done in this country.

There are different movements of handling, depending upon the kind of traffic. Thus, inbound cotton on account of the many marks passes upon or over the pier and not to lighters on the off-shore side of the ship. Much is held temporarily awaiting lighters, but eventually it is almost all placed upon the lighters alongside the piers. Inbound copper in mattes, strange to say, passes over the piers for immediate or final lighterage. Both copper and cotton are assorted and distributed as each comes from the ship. Such freight as dried apricots, etc., each box weighing twelve and one-half kilos (28 pounds), is placed on the piers without first assorting, but is afterwards separated according to marks and also according to the different brands such as "choice," "extra choice," etc. To assort 2,000 boxes of dried fruit into five piles requires six or seven men including the foreman for two hours, costing from 13 to 15 cents per ton. When mechanical methods are employed, this assorting can be done between decks saving most of this expense.

Lumber, especially southern pine, is difficult and expensive to handle, the expense amounting as high as 75 cents a ton. There is much to be learned in studying at separate localities the movements of different kinds of freight, among which can be mentioned bags of rice, barrels of spirits, cases of dry-goods, furniture and a long list of others. All of this, as well as the stevedore's work, must be known before the mechanical methods can be recommended.

In the United States, export freight is hoisted from off-shore lighters by man-power, steam winches on lighters, and by dock or ship's winch; from other lighters alongside the pier, by handtrucking across or along the pier floor by manual labor to within reach of the winch and then hoisted; dray freight is unloaded on places upon the pier floor as directed by the floor men, and then, after being selected by the stevedores is trucked to the ship's side and hoisted by the winches.

Of import freight, part is swung over the ship's side by winches either upon off-shore lighters and often burtoned to the fall of the lighterage winch. Part is swung upon the pier side either directly or by burtoning, and then assorted, and distributed by surface trucks to different places marked on the pier floor and tiered by hand, or else to the lighters.

The movements of coastwise freight is about the same except that part is trucked to or through the side ports. The side port is evolved from the use of hand trucks.

The maximum number of drafts by the ship's winch through the hatch per hour is 40. Coal consumption per day per winch is one-half ton costing $1.75. Hoisting capacity per winch three tons. Average number of drafts per winch per hour, 32¼. The dock winches average about the same in capacity and operation. The so-called "cargo hoists," above the edge of the roof are chiefly used in connection with dock winches.

Most lighters are equipped with a mast and a hoisting boom, the barges seldom. A few have steam-power winches. On account of there being so much waiting and delay of the lighters at the different terminals, the expense, for the licensed engineers and the attendant costs, would be far more than the time saving due to the quicker freight handling.

If the steam-power winch lighter could be kept continuously in service it would be economical to replace men by steam.

Man-power winches are slow and costly to operate, there being employed two or four men to operate each winch.

Electric winches, with electric connections with the piers, would fulfill the requirements as to economy of operation and rapidity of movements, and without the excessive delay expense. These winches by clutches could be operated by man-power whenever necessary.

Most of the terminals are now furnished with electricity, and plug connections could be located at suitable intervals along the side of the piers so that the electric current could be readily available. Storage batteries are used upon lighters in Germany.

The winchmen and others handling freight upon the steamship piers, when employed by the hour, receive 30 cents per hour up to 6 P.M., 45 cents per hour after 6 P.M., and 50 cents per hour on Sundays.

The number of men at each point of loading, that is at hatches and in the holds, are 14 men at each, where there are three loading points or 42 men in all; if there be five loading points 12 men at each or a total of 60 men. It is essential to know all the freight movements to comprehend any mechanical adaptation so as to secure good results.

Foreign Methods.—At foreign ports, the various types of gantry cranes

are used, both fixed and traveling. The half-arch crane as illustrated is preferred at Antwerp to serve the open space between the shed and the vessel. Liverpool on the other hand has 170 roof cranes in one section. These gantry cranes have a hoisting capacity of one and one-half to three tons and the motors are generally of 250 or 500 volts. With a 6,000-pound load, the cost of electric current is given as 0.63 of a cent per ton, with a 1,000-pound load 1.2 cents per ton. This is at the rate of 8 cents per kilowatt-hour, more than double the rate in New York.

The speed of hoisting three tons is two feet per second, or four feet per second with half a ton. In one case the average load at the station was $3\frac{3}{10}$ kilowatts per crane when 20 cranes were at work and $2\frac{1}{5}$ kilowatts when 70 cranes were in operation.

The performance of cranes is given in cycles. The cycle often mentioned consists in attaching and hoisting the load 50 feet, swinging 150 feet, lowering to the platform, releasing the hook, raising, swinging back and lowering the hook to the starting point.

Twenty cycles per hour can easily be accomplished although claims are made for 40 or more. There are most complete records of the performance of these cranes at Hamburg.

The ship's winch is in most cases, all conditions considered, as rapid and economical as these gantry cranes. The winch, however, can only place the freight upon the edge of the pier while the gantry crane can serve a half circle upon the pier some 45 feet in radius, loading and unloading cars and serving the space within this area.

The cost per ton of thus swinging the freight upon the pier, either by winch or gantry, is from two to five cents per ton; but the after-cost by manual labor for distribution and tiering is over 30 cents per ton additional.

Manual Labor Costs.—The following detailed figures will make clear the cost of handling by manual labor.

Loading 2,000 Tons in 17 Hours.

Number of men employed	150
Tiering men (extra)	20
Men in vessel included in the above	60
Number of truckers	90
Tonnage of off-shore lighters	1,000
Tonnage across piers	200
Tonnage from drays	800
Hand truck loads	10,955

Loading 2,000 Tons in 17 Hours—Continued.

Average weight of each load, pounds	184
Average trips per truck per hour	12
Cost per ton handled, labor only including tiering, cents	36.6
Cost of tiering alone, cents	3.71

Discharging 2,000 Tons in 17 Hours.

Number of men employed	170
Off-shore lighterage tonnage	200
Lighterage tonnage across pier	1,300
Dray freight tonnage	500
Average truck load, pounds	600
Average trucking distance and return, feet	600
Speed of trucking per minute, feet	120
Time per round trip, minutes	12
Cost per ton handled including tiering, cents	39.15
Cost of tiering alone, cents	7.44

It will be noticed that the great expense is not the transferring the freight between the vessel and the shore, but in the subsequent movements such as rehandling, assorting, distributing and especially tiering.

Principles of Freight Transference.—From the above there can be determined what conditions must be fulfilled by any machinery to satisfy the requirements of freight handling. These may be condensed into serving all the space by machinery, with no rehandling and with continuous rapidity. These three principles are essential in securing rapidity and economy.

Earlier Methods.—In the United States, import and export freight is transferred by winches through the overall hatches upon the pier and then distributed by means of men's shoulders or handtrucks. In coastwise service, in addition the men and handtrucks pass through the side ports.

At European ports the work at the hatches is done partly by the winch but mostly by fixed or traveling cranes of the gantry type, and then the freight is handtrucked into the sheds. Sometimes low trucks, with two, three or four wheels are drawn by horses, and trucks with steam derricks are in use, but for rapid transference these latter occupy most valuable floor space and cause congestion.

After the freight has been placed upon and near the side of the pier, there is no provision for rapid and economical distribution. The handtruck, though expensive, provides for assorting and distribution and requires far

less surface area than horse or power trucks. Besides the expense and floor congestion resulting from lack of capacity when large numbers of hand-trucks are in service, the difficulty of securing large numbers of men of the good old longshoremen type and the possible labor troubles, are some of the incentives to apply, without delay, machinery to do most of the work.

Harbor terminal improvements so as to obtain sufficient berthing, transshipment and storage capacity are expensive, and the units of expenditure are millions of dollars. Extensions are continually being required and on account of the long time in construction must be planned and the work started long before the existing facilities are overcrowded. If by mechanical methods greater rapidity of loading and discharging can be secured, removing delay at the congested points, then the same lineal frontage and pier space can accommodate more vessels within a given time, thereby greatly adding to the capacity of the harbor terminals, and effecting the saving of many units of extension expense. In the opinion of the author, in certain cases it would be possible to reduce the loading and discharging time by nearly one-half.

The record of one year of 804 steamships, gives an average of two and two-fifths days for loading and two and one-half days for discharging. The total tonnage was over 2,100,000. In one case where there were six discharging points on a ship only three were utilized. To take care of the three points required 190 men to keep the freight continually moving; from six points would have required 325 men, and they were not available. The fact that much greater terminal capacity can be obtained by mechanical methods without floor congestion, effecting a saving of many millions of dollars which would otherwise have to be expended for improvements and extensions, deserves careful and thorough investigation by executives and engineers.

Later Machinery.—Besides the winch and gantry cranes abovementioned there is the long distance overhead conveying and hoisting machinery such as the English transporters, the German man-trolleys, the American T-rail telphers and the lower-flange conveyors. In addition there are the overhead transfer-tractors and transfer-hoists with the movable tracks, installed at the later equipped German ports.

Keeping in view the work to be done, and selecting the best features of all the machinery that has been herein mentioned, there can be obtained the desired mechanical serving of all space, no rehandling by manual labor and continuous rapidity.

In a paper on "Wharf Equipment" presented by Mr. Llewellyn Holmes before the Institution of Civil Engineers of Great Britain, he states that "dock companies will be expected to provide plant, not for discharging and

loading only, but for conveying goods to and from the ship's side as quickly as possible." Referring to the usual methods employed, he says "Whatever description of crane is used, delay will be generally caused * * * in getting the sling loads into the shed * * * . Where the distance is over 100 feet, it will probably be found much cheaper and quicker to use an overhead runway, lifting and carrying the whole sling load to the pile. This not only saves labor, but clears the way for the next sling deposited by the crane."

This is quoted to show the trend of the papers before the English civil engineers.

It may be asked why are the overhead runways not more generally installed? The answer is instructive. Many visit the Tilbury Docks, and the West India and Royal Albert Docks at London, and suggest similar installations for the ports of the United States, forgetting that the Tilbury Docks were finished in the early eighties and the other docks mentioned even earlier and that additions usually conform to the existing methods. That the installations are ancient, is true of Continental ports such as Hamburg and Antwerp, and at the latter port they are still installing hydraulic instead of the better electric cranes. The reason is given that as the hydraulic cranes have given good service they have been adopted for later installations. This does not mean that there are not many electric cranes in use at the port of Antwerp. Hydraulic cranes have not, however, been recommended for American ports.

Some steamship companies prefer to use the ship or dock winch and in such a case, the long-distance conveying machinery can take from the ship's side and then convey. Preferably the freight should be taken directly from the ship's hold by the far transferring mechanism.

The space most available for conveying is overhead, thereby utilizing space largely unoccupied. The overhead runway system of conveying in connection with hoists fulfills more essential requirements than any other. It is the equivalent of an overhead traveling winch. In some cases, where there is an extensive floor space, three or four-wheeled power surface trucks with derricks can be used successfully in connection with overhead runways and give good results. This combination will often be installed.

This overhead hoisting and conveying machinery consists in fixed and movable tracks, overhead travelers of different types such as the transfer-tractors and transfer-hoists. The overhead tracks consist of T-rails upon the top or upon the lower flanges of steel girders.

Movable Tracks.—Where tracks are movable they are attached to the traveling crane of the various types such as the gantry and traveling-shop

cranes, and other types, but without the usual swinging jib. The motive power is electricity.

In accordance with the above, and from a careful consideration of all types of hoisting and conveying machinery, the traveling crane is the only machine which will serve large spaces without rehandling.

The standard overhead traveling-shop crane takes up no floor space in its operation. No aisles or alley ways need to be reserved from the valuable floor space so as readily to reach any consignment pile. It can tier most advantageously, and its great positive value is proved by its universal adoption.

Although it will tier and serve space without rehandling and produce no floor congestion, yet it will not give the rapidity for the continuous service required in freight movements.

If, after a load has been raised, many men must wait for the crane to pass to the end of the station, place its load and return, there would be much labor delay.

If, by attaching a track upon each side of a crane as is now done in Germany, Holland, Belgium and France, and adding a gliding or sliding connection by switches between the movable and fixed tracks, so that transfer-tractors with their traveling trains can pass from the fixed tracks to the movable cross tracks, utilizing the overhead shop crane for the interior of the shed and the traveling gantry crane with a loop or the walking crane for either interior or exterior work, then there can be added to the other indispensable features of crane movements the essential continuous rapidity.

Conveying and Hoisting Machinery.—The conveying mechanism consists of a transfer-tractor drawing after itself four or more trailers with an electric hoist suspended beneath each trailer. The four hoists are controlled by the transfer-man who rides in the tractor. The hoists can be operated simultaneously or independently of each other. Each hoist raises or lowers one consignment. The speed of travel is between eight and ten miles per hour. Each hoist has a capacity of two tons with a temporary reserve capacity, at the usual hoisting speed, of from 75 to 200 feet per minute. Two hoists can be combined and raise four tons.

As each consignment will average about 1,500 pounds, therefore there will be an average train load of 6,000 pounds. This method means that the freight will be assorted as it is raised not requiring skilled labor, and then distributed and tiered. There are, therefore, the following mechanical elements:

An overhead runway system with electric carriers and hoists designated either as transporters, transfer-tractors and transfer-hoists or by many other

names. These are most extensively used. There is also the traveling-shop or gantry crane of universal adaptation, for transporting and adjusting the movable tracks.

By means of this combination, cargoes can be assorted, raised, conveyed and distributed to and from any place upon the pier floor, or to the cars, drays, lighters, open yards and the warehouses, all without rehandling, and by means of circuit tracks and diverse paths, with continuous rapidity. Provision is also made for the other operations such as inspection, routing, weighing and checking. By means of gravity rollers extending into the cars, a load lowered by the hoists upon these rollers will pass by gravity into the cars, and in some instances to the ends of the cars.

Capacity of Transferage.—With an average load of 6,000 pounds at nine miles an hour, to transfer 300 tons per hour, the average pier distance of distribution being about 600 feet, would require eight trains including reserves. This number of trains can be increased to more than double, serving five hatches, before any congestion is reached.

Installation and Operative Costs.—It will be noted that great capacity can be readily obtained by adding trains. The cost of installation on an operative tonnage basis will be between one and two cents for each ton transferred between the ship and the tiered pile in the shed.

By adjusting the layout to the volume of the freight, the installation expense can be made proportionate to the tonnage.

Including tiering, the cost for manual labor varies between 30 and 40 cents per ton. Variations from these figures may depend upon methods of bookkeeping or on exceptional circumstances.

The following under certain conditions would be the operating costs by mechanical methods allowing margins for contingencies.

Mechanical Operating Costs, 2,000 tons, Loaded in 9 Hours.

5 conveyor men, 9 hours at 30 cents per hour.....	$13.50
10 hookmen, 9 hours at 30 cents per hour.....	27.00
2 winchmen, off-shore freight.....	5.40
4 switchmen.....	10.80
60 holdmen, 12 at each loading point.....	162.00
Total wages 2,000 tons loaded.....	$218.70

Costs per Ton.

Wages	$0.10935
Interest, maintenance, and amortization at 6 per cent. compounded, equal to 10 per cent. simple interest	.01043
Electric power	.01050
Total cost per ton loading, including tiering	$0.13028

Discharging 2,000 Tons in 9 Hours.

5 conveyor men, 9 hours at 30 cents per hour	$13.50
10 hookmen, 9 hours at 30 cents per hour	27.00
2 winchmen	5.40
2 switchmen	10.80
70 holdmen, 14 at each discharging point	189.00
Total wages discharging 2,000 tons	$245.70

Costs per Ton.

Wages	$0.12285
Interest, etc	.01240
Electric power	.01050
Total cost per ton discharging including tiering and assorting	$0.14575

These figures apply to freight transference at certain Atlantic port piers.

The manual labor costs included the wages on the truckers, routers, checkers, holdmen, etc., but did not include those who received monthly salaries, such as the stevedores, superintendents, etc.

If of the 2,000 tons of freight handled daily on one pier 50 per cent. or 1,000 tons were distributed by manual labor, then on the 1,000 tons there would be a daily saving at the lowest manual labor costs and the highest mechanical costs of about 22 cents per ton or $66,000 annually.

If the average charter value of each ship in the fleet be $330 per day then by the increased rapidity of loading and discharging there would be an additional saving in this case of $330 per day for each day.

If the rental of a pier be $80,000 per annum and double the number of vessels can be loaded and discharged at this pier, then the expense per ton for rental would be reduced by one-half.

The following figures indicate the saving in the investment in port installations by high tiering. The marine ton is 40 cubic feet, but from comparison of the weights and cubical contents of over one hundred articles of merchandise within transshipment sheds, it is evident that 60 cubic feet per ton would give a more nearly correct average for estimating the storage space to be provided. In one transit shed, the floor area was 80,000 square feet, but of this, not more than one-third was available for storage, the rest of the floor space being reserved for aisles, gangways, passageways for drays and trucks, and offices.

Space for Cargoes.—It appears that there should be reserved in the shed not less than 100 cubic feet for each ton. A cargo of 10,000 tons miscellaneous cargo, tiered 20 feet in height, would require a floor space of only 50,000 square feet. If, as is generally accepted, that five feet is the average height of tiering by manual labor, then there would be required 200,000 square feet for 10,000 tons. A pier 400 feet long by 125 feet wide, tiering 20 feet high, would accommodate 10,000 tons, but a pier 1,000 feet long and 200 feet wide would be necessary for the same amount of freight when there is only five foot tiering.

Subjects for Future Discussion.—There are many other features in connection with this freight transference which should be discussed, but time prevents. Among these may be mentioned, the type of shed walls and doors; material of the shed floors; the reasons for the hoisting capacity of the cranes; the necessity for special cranes up to 150 tons capacity; location of the tracks which should be flush with the road, correlation between the sheds and warehouses; provision for cart area for cart traffic; comparative costs between the operation of winches and gantry cranes; the economy in the purchase of land by being able, by long distance overhead runways to occupy areas located at a distance from the pier; the terminal charges of the stevedores and master porters; the hourly rates for crane service, etc.

Machinery Floats.—The reducing of slip congestion by means of floats 25 or more feet in width, equipped with overhead tractors, hoists and extension tracks for transferring freight between vessel's hatchways and several lighters and barges, and for holding temporarily on the floats freight still in the slings, these, and many other features are worthy of attention; and it is hoped that papers by others on freight transference will be presented.

In summing up, it may be said that the advantages of mechanical methods for package freight movements of which the most important is the lifting or hoisting, consist in:

First.—Greater rapidity in loading, discharging and distributing. The time of transference can be reduced by one-half in comparison with manual labor.

Second.—Economy per ton handled. A saving effected of at least one-half.

Third.—Increased holding or storage capacity on piers.

Fourth.—Greater working capacity of each pier.

Fifth.—Less port detention, meaning fewer ships to transport a given tonnage.

Sixth.—Saving in port investment.

Seventh.—Improved dray service, and reduction in damage claims from breakage.

Eighth.—A larger return from the money invested in cargo transferring machinery, than from any other element of a transportation system.

No one can long ignore the many changes in all classes of traffic in the transition from the local intra-trade to the national or international inter-trade.

Reference might be made to other economies which are the natural results of greater rapidity in these freight movements, but it is evident that there are many opportunities for improvement. Wherever large numbers of men can be replaced by machinery there has always resulted rapidity and economy.

Quoting from the first line of the 1911 manual of the American Railway Engineering Association, "Times change and we change with them." If we do not, and become laggards in the march of progress and improvement, it will be said of us as of others, "His place will know him no more."

It is hoped by the author that this paper, necessarily incomplete, and not including quay equipment for harbors or inland rivers, will provoke criticism and discussion, especially at the present time, so that the many future harbor installations in the United States, for which large appropriations have been made, will be in accordance with the recommendations of members of the Society of Naval Architects and Marine Engineers.

DISCUSSION.

THE PRESIDENT:—You have listened with a great deal of interest to the graphic presentation of the paper on "Cargo Transference at Steamship Terminals," by Mr. Harding. Are there any remarks to be made on this paper?

MR. W. D. FORBES, *Member of Council:*—Mr. President and Gentlemen, this paper is one of the most interesting, to me, that has ever been presented to our Society. It is on a subject that has been given attention in a rather spasmodic

manner. The transportation companies have been so much engrossed in getting material from one point to another, that they have not given the attention they should to the matter of handling it after it has reached its destination; in other words, they have been, figuratively speaking, rushing water to a thirsty man with great speed, but have not given him even the poorest kind of facilities to drink it.

I have taken unusual interest in the subject, and in my observation the ludicrous side of it has presented itself to me. On one occasion I was watching the loading of freight cars at one of the terminals in New York City. A man came along with a 400 pound package, and proceeded to put it in the car, directly after him came a man carrying three five-sixteenths inch carbon tubes bound to a stick, which weighed about six pounds, and both packages were carried the whole length of the pier, something like 500 feet.

I have studied this question and have come to the conclusion that the most satisfactory system of shed will be a two-story one, the lower portion being absolutely free of freight, and used exclusively by the trucks; in other words, the trucks will come in on the lower level, and then go forward to hoists or elevators in the building; the second story will be devoted exclusively to the use of storing the freight. It costs very little more to hoist freight twenty feet, once you have hold of it, than it does to hoist it ten feet. I would have the whole central part of the second story open, and I would have a form of tramway on each side of the opening, on which freight could be moved, so that the freight could be put on these tramways and taken to any part of the storage floor. In loading freight on the pier, you would have the team under the opening, and lower the freight onto the trucks with very little difficulty, having the lower portion of the pier only used for trucks so they can pass each other, as the docks will be amply wide. You saw on some of the screens how congested are the freight piers—the horses seem to be swallowed by it. With the plan I suggest, I believe that could be entirely obviated.

I think the naval architect can with much benefit give a great deal more attention to arranging vessels so that the vertical hoist can be used. With the present congestion on our piers and docks, there is much time lost, which results in a costly detention of the vessels.

Mr. A. George Mattsson, *Member:*—The last speaker mentioned the fact that in the ordinary coastwise service, the vessels have often to wait a long time before unloading is begun, and on this account much loss of time ensues. On the Great Lakes, it is just the opposite in a great many cases. Particularly in the ore trade, the ships run along at a comparatively low speed, say 11 statute miles per hour, and, coming to the dock, remain there possibly three or four hours to be loaded, then start out again, returning to the lower terminals, there to be unloaded in from three to six hours.

The capacity of our vessels on the lakes handling coarse freight has been largely increased in the last few years, and they are doing additional business also, because of the increased facilities for loading and unloading; that is, there is less retention

of the vessels in port, and they are thereby enabled to accomplish more. As a matter of fact, many vessels are lying in port idle on account of the excellent loading and unloading facilities which have been introduced in the last few years, and it is decidedly striking that the mechanical apparatuses for unloading have reached such a high state of efficiency, thus enabling fewer boats to do the same amount of business.

SIR WILLIAM HENRY WHITE, *Honorary Member:*—I think sir, that the author of this paper put his finger upon the fundamental principle of handling cargoes, when he said that all arrangements for loading and unloading cargoes should be governed by the nature of the service to be performed. While that is a very broad generalization, it is perfectly true—I heartily endorse it, but it covers a great deal of ground. The pictures that we have seen thrown on the screen illustrate attempts which have been made to fulfill that condition, and indicate how varied may be the solutions.

Speaking as a naval architect, I would like to say that ship designers ought always to provide as far as possible in the designs of all ships the means of readily shipping or discharging cargo; they ought in fact to make ships suitable for their services.

An extreme illustration of that principle has been shown in steamers in which that rapid shipment and discharge of cargo which is essential to commercial success has been secured by special structural arrangements. Naval architects know perfectly well that such ships as those cannot be sent over the ocean to carry freight, but seagoing ships can be and are being designed in which similar facilities for shipments and discharge of cargoes have been provided. I am well aware that a Whaleback once came to Liverpool—in fact, I visited her in that port. She got there and got back again to America, and that is all that need be said about the trip; because we know perfectly well that the attempt to adopt the Whaleback system, which was made in England, resulted in the development of quite a different type for seagoing work. It is a fact, which ought to be recognized, and which I always endeavor to bring into prominence, that in later years great skill and high scientific work, in my judgment, have been devoted to the design and construction of cargo steamers in England. We are apt to think about big steamers and costly warships, but we ought not to overlook the fact that some of the most remarkable developments and important applications of scientific principles to the construction of steamships in recent times are to be found in cargo steamers. Their hull-structures, their equipments for handling cargo, the arrangement of the hatchways, and formation of the holds, so as to facilitate loading and discharging—these and other features have received careful consideration, and the construction of cargo steamers has been vastly improved.

In carrying out these improvements, designers have run up against serious difficulties in the due maintenance of the structural strength. I could tell you of cargo steamers which have broken and sunk, because the cargoes they had to carry

and the arrangement of the upper part of the structures left the ships without sufficient strength against compression. From accidents of that nature there has arisen a necessity for better and more scientific design; and those who have followed the matter will know how many rival and competing types of steamers have been developed, all of which differ essentially from ships built ten years ago, and embody scientific principles in their structures, as well as better means for handling cargoes.

The lifting appliances of the ship obviously ought always to be made as complete and efficient as possible, and the extended use of electricity is greatly assisting rapidity and ease of control.

A few words about the harbor authorities? In England, in the construction of new docks and the arrangement of warehouses, attention is always paid to the handling of cargo. If one wishes to see how much attention has been devoted to that side of the subject in recent years, as compared, with what was formerly given to it, one only needs to go to Liverpool and walk through the docks, passing from the older docks to the later docks.

In England we have one difficulty which I suppose is not felt much here. In some of our docks we have to deal, if I remember rightly, with a rise and fall of tide of as much as forty feet. That is not a comfortable thing to face in connection with the use of lifting appliances.

I was at Prince Rupert the other day, where there is a rise and fall of tide amounting to 27 feet. In England the use of enclosed docks is general because of these tidal conditions. Ships enter these enclosed docks, wherein a constant level of water can be maintained, and the relation of the ship to the wharf is unchanged. In the latest development in English ports, that on the Thames, after considering the whole matter, it has been decided that further enclosed docks shall be built. The key-note of the whole situation, as the author says, is consideration of the services to be performed. The cooperation of all concerned—civil engineers, mechanical and naval engineers, and port and harbor authorities is also essential if the best results are to be obtained.

Mr. Robert H. Rogers (Communicated):—I cannot lose this opportunity to endorse Mr. Harding's paper on Cargo Transference. As a student of the intricate problems presented by freight traffic in general and the terminal handling of package freight in particular I have been handicapped by the lack of comprehensive data and statistics covering this important and costly class of work.

Probably 90 per cent. of the data of a reliable nature on this subject available to-day is due to the unremitting efforts of Mr. Harding and is found in the form of short papers and addresses published in technical magazines and in the proceedings of traffic associations and technical societies such as this.

One can hardly conceive of more difficult figures to analyze, segregate, and properly label than those covering the cost of handling freight in terminals. In the first place these costs are not generally understood by those in charge and in the second place fear of harmful comparisons seal the lips of those having approximate figures at their disposal.

In contrast with the published volumes of information regarding the movement of merchandise on the wheel and on the keel we have for the equally important movement of merchandise in terminals only the scattered, though thorough and comprehensive, work of Mr. Harding.

In view of the rapid growth of mechanical systems for handling freight and the engineering problems involved, I believe that Mr. Harding, however deeply we are indebted to him, owes it to the traffic and engineering fraternities to collect his various papers into a volume compiled as a standard reference book covering this vast field of human endeavor which stands in urgent need of such a work.

It is with pleasure that I add the following data and description to Mr. Harding's paper:

One feature of cargo transference which heretofore has been a source of great labor expense is not clearly brought out in this paper. I refer to the distribution of cargoes to warehouses for storage, and the piecemeal return of this material to the bulk-head for lightering. The great warehouses act as flywheels between the periodic crops of the world and the constant demand of the market—being the farmers' granary on a very large scale. Where a large number of warehouses are maintained in connection with a marine terminal they must necessarily cover considerable territory so that the products intended for storage must be transferred anywhere from 500 feet to three quarters of a mile. Not only are the distances apt to be relatively great but the courses followed must be numerous, crooked, interlaced and overlapped. Take for instance the Bush terminal where cargoes are distributed from seven great piers to 123 warehouses and then are returned to the piers and bulk-heads or to cars and drays. The use of an industrial railway for such work would involve so many miles of track and trolley construction that the first cost would be prohibitive. Then such a method involves a "system" which does not readily lend itself to short jobs, hurried work or to a large number of conflicting unit movements. The same objection in an intensified way holds true for a telpher or overhead system.

The battery truck crane shown on Plate 84 of this paper was devised expressly to handle this class of work in an economical manner, and at a first cost that is wiped out during the first year of service.

Where the merchandise has to be carried only five hundred feet or less the loads of one ton are carried on the crane hook at about nine miles per hour, delivering a load every two minutes if the distance is three hundred feet. The lower cut on Plate 84 shows 1,600 pounds of plumbago which was moved at the rate of 30 tons per hour. Where the distance involved is over five hundred feet the material is loaded onto roller bearing trailers and towed behind the machine as shown in the upper cut. By this means thirty tons of cotton can be moved one-half a mile in an hour at a cost of less than three cents per bale for the transportation and labor of loading and unloading the trailers. It is customary to use three trains per machine, that is, while one train is being loaded the second is being unloaded and the third is on the road between, thereby cutting out waiting at either end. In other words, one man and

one machine keep 600 sq. ft. of cargo dock active. In the case of heavy merchandise, such as burlap, barrels of oil, rocks, logs, etc., a second machine is used to load the trailer with its crane. On a hurry-up order for cotton recently given at 9 A. M. the foreman had 48 bales alongside the lighter from half a mile away at 9.25 and three hundred bales were on board at 11.30. This illustrates how quickly the system can be put in motion, and how effectively it acts.

From logs kept by the operators of the four battery truck cranes used by the Bush Terminal Co. it has been found that the average distance hauled is 900 feet and the maximum three-fourths of a mile. Packages are delivered at the rate of three a minute and at a cost of one-third cent per package or 3 cents per ton.

About 900 tons, representing nearly 8,000 packages, are handled per week by each machine. The tractive effort is equal to that of a five-ton locomotive on rails and its lifting capacity is nominally one ton, but this is frequently exceeded. A battery truck crane with a liberal number of trailers, say twelve, constitutes a transporting system good for one or one million packages to be transported one hundred or five thousand feet without an elaborate system of management, and with very low first and maintenance costs.

THE PRESIDENT:—Is there any further discussion upon this paper?

On your behalf, I will extend to Mr. Harding our sincere thanks for the courtesy he has shown in presenting this paper to us, and we will be very glad to hear from him again in the future.

There are one or two matters of business that should be taken up at this moment. They will not take long, and I will ask the Secretary to read the reports of the Committees appointed by the counsel.

SECRETARY DANIEL H. COX:—The Council at its last meeting took up the question of amending the method of election of officers to the Society, and these are the suggested amendments recommended by the Council.

Section 1, Article IV, under the head of officers, now reads as follows: "The officers of the Society shall consist of a President, Past Presidents, twelve Vice-Presidents, twenty-four Members of Council and a Secretary and Treasurer."

It is recommended that this Section be altered by introducing after the words "Past Presidents" the words "Honorary Vice-Presidents."

Section 4, Article IV, now reads as follows: "The term of office of the Vice-President shall be six years. Prior to the Annual Meeting in 1906 the Executive Committee shall by lot divide the present list of Vice-Presidents into six classes, so that the term of two of their number shall expire at the end of 1906 and two others at the end of 1907, and so on to the year 1911. The Vice-Presidents to fill the vacancies occurring each year in any class shall be elected by the Council from their own membership. Retiring Vice-Presidents shall be eligible for re-election."

All of the first two sentences are to be stricken out and the following substituted: "The term of office of the Vice-Presidents shall be three years. The Vice-

Presidents whose terms by election now expire in 1911 and 1912 shall expire as of December 31, 1911; and whose terms now expire in 1913 and 1914 shall expire December 31, 1912; those whose terms now expire in 1915 and 1916 shall expire December 31, 1913. Beginning with the four Vice-Presidents elected for the term ending December 31, 1914, there shall be four Vice-Presidents elected each year to take the place of those whose terms expire."

A further amendment to Section 4, Article IV, is offered as follows—the following paragraph to be added: "Honorary Vice-Presidents shall be chosen from the list of Vice-Presidents who have had at least ten years service as Vice-President. They shall be chosen at the meeting of the Council next prior to the annual general meeting of the Society and must be the unanimous choice of all members of Council present. Not more than two Vice-Presidents may be elected Honorary Vice-President in any one year."

There is a further amendment to Section 5, Article IV. This paragraph is rather lengthy, and I shall not read it. The members are familiar with the method of election of officers at the present time. The Council suggests that all after the first sentence be stricken out and the following inserted in place thereof: "Prior to September 1st of each year the President shall appoint a Nominating Committee of five (Members and Associates both being eligible). This Committee shall prepare a list of six Members and two Associates to fill the vacancies occurring in due course at the end of the year, and shall forward the same to the Secretary by September 1st. This list of names shall be mailed as soon as practicable after September 1st of each year to Members and Associates. The ballots shall be returned by mail to the Secretary and canvassed at the annual meeting.

When the said list of names has been sent out by the Secretary, should there be a desire on the part of Members or Associates to suggest another list of candidates for the Council, any twenty Members and Associates may unite in submitting another list to the Secretary which shall also be sent out to the membership to be considered in connection with the list already sent. In case such additional nominations are made the six members who receive the highest number of votes shall be declared elected members of Council and the two associates receiving the highest number of votes shall be declared elected Associate Members of Council, in each case for a term of three years."

These amendments were recommended for consideration by the Council.

The President:—You have heard the amendments which have been proposed. Are there any remarks to be made upon the same? Does any one require further information on the subject?

The present provision of the Constitution calls for amendments to be reduced to writing and signed by not less than ten members and forwarded to the Secretary, which was done. The Council considered the amendments and unanimously approved the same, and they are now presented to you for approval. If approved by two-thirds of the members present voting by ballot, if a ballot be demanded, the

amendment shall be adopted. Is a ballot demanded? If there is no ballot demanded, are you ready for the question?

(There being no ballot demanded, the amendments were put to vote and unanimously carried.)

THE PRESIDENT:—The amendments are carried and now stand as part of the Constitution and By-Laws of the Society.

Another matter brought before the Council was a suitable recognition of the courtesies extended to our Society by the Institution of Naval Architects, and this resolution was drawn up and submitted to the Council, approved by the Council, and recommended for your approval.

The Secretary read the following resolutions:

"Whereas, The Institution of Naval Architects, in celebrating with a Jubilee Meeting the Fiftieth Anniversary of its incorporation, conferred upon the Society of Naval Architects and Marine Engineers, the honor of an invitation to be its guests upon the happy occasion, extending from the 3d to the 8th of July, 1911; and

"Whereas, A number of the official representatives and other members availed themselves of the opportunity to be present and received many kindnesses and attentions through a series of meetings and festivities conceived with infinite courtesy and executed with precision; therefore, be it

"*Resolved*, That the Society of Naval Architects and Marine Engineers, at this its first meeting since the occasion referred to, now cordially expresses its sincere thanks and appreciation; and further conveys its wishes for the long continued success and prosperity of the Institution of Naval Architects, its President, Officers and Members."

THE PRESIDENT:—You have heard the resolution as presented to you by the Council.

MR. WALTER M. MCFARLAND, *Vice-President:*—Mr. President, it gives me very great pleasure indeed to move the adoption of these resolutions. I had the pleasure of attending the Congress as one of the delegates representing this Society, and I cannot speak too highly of the courtesy and good feeling and the splendid entertainment that was extended to us by our cousins or our brothers, as you may choose to call them, on the other side of the water. It was the second time I had attended one of these Congresses, and I thought when I attended the other Congress that it was the very best time I ever had in my life, but this second time was fully equal to the first, if it did not surpass it. The cordiality of our reception, of course, could not be exceeded, because the first time it was all anybody could possibly wish, but on the occasion of our second visit, there were in addition to the cordiality of the members and their personal entertainment, some special features

of Government entertainment which added a certain brilliancy and éclat to the occasion and made it practically perfect. As I say, it gives me pleasure to move the adoption of these resolutions, and I suggest that they be suitably engrossed and sent to the officers of the Institution of Naval Architects.

MR. EDWARD P. BATES, *Member:*—I desire to second the adoption of these resolutions, and in doing so I think it is only fair to state to the members who did not have the privilege of meeting with the members of the Institution of Naval Architects on the occasion of the Congress held last July, that all that Mr. McFarland said is most true, and if I could add to it I would say that our English friends are the princes of entertainers. When we went to the headquarters of the English Society in Adelphi Terrace we were met as though we belonged there, and that was the spirit which was manifested all the way through the meeting. You, yourself, Sir, were present, and know that is a fact, and at every meeting, and at their entertainments, we were taken in just as though we belonged to the home Society, and I do not think there are any words strong enough in the English language to convey the expressions of our feeling in regard to the courtesy and attention that we received from the Institution in London. If so, I would much like to embody them in my remarks.

THE PRESIDENT:—Are there any further remarks upon this question? The President, in his address yesterday morning, tried to show his appreciation of the courtesies that were tendered to the representatives of this Society, and what Mr. McFarland and Mr. Bates have said indicates the amount of attention that we received. Mr. Bates says we were "taken in." I assure you we were taken in, not as strangers but as friends and brothers. I put this question to you, if you are ready—those in favor please say aye, contrary minded, no. The resolutions are unanimously carried.

The resolutions will be suitably engrossed and sent to the Institution of Naval Architects.

As you were informed yesterday, a change in the Secretary-Treasurer is made necessary by the long illness of our dear friend, Captain Baxter, and a Committee was appointed to prepare the resolutions mentioned. Will Professor Sadler please read the report of that Committee.

PROFESSOR SADLER:—Mr. President and Gentlemen, the report of the Committes is as follows:

At the annual meeting of the Council of the Society of Naval Architects and Marine Engineers, the President read a personal letter from the Secretary, Naval Constructor W. J. Baxter, U. S. N., expressing regret that the state of his health and probable assignment to duty remote from the city of New York, made it necessary, in his opinion, that a successor be elected at the present general meeting of

the Society. This intimation was received by the entire Council with expressions of the deepest regret, and it was only after being assured that Mr. Baxter's decision was final that the Council was willing to consider the selection of a successor. It was then proposed and unanimously approved by Members of Council that suitable resolutions be prepared, making formal recognition of Mr. Baxter's services to the Society as Secretary and the great regret felt by his fellow-members, individually and collectively, at his retirement from that office. In conformity with the expressed wish of the Council, the President appointed a Committee to prepare suitable resolutions, and this Committee begs to submit the following report:

Naval Constructor Baxter is a Charter Member of the Society and has been its Secretary since December, 1903. During the period of his secretaryship, he has held also a position of conspicuous importance and responsibility under the Navy Department, the exactions of which have made his devotion to the work of the Society more notable than is ordinarily the case with those holding similar positions in scientific institutions. How well Mr. Baxter has discharged his important duties under the Navy Department would seem to require no other comment than the simple statement that he was the responsible technical officer in charge of the construction of the U. S. S. Connecticut, the present Flagship of the Atlantic Fleet and her later and larger consort, the U. S. S. Florida; while those of us who have been in close touch with the management of our Society, and followed its growth during Mr. Baxter's term of office, realize only too well that its present excellent condition is due in very great measure to his untiring and intelligent performance of duty as its Secretary.

Your Committee, therefore, recommends this report and the following resolution to the Society for such action as it may deem appropriate:

Resolved, That the President, Council and Members of the Society of Naval Architects and Marine Engineers in annual meeting assembled have learned with profound regret of the inability of Naval Constructor W. J. Baxter, U. S. N., to continue his most valuable service as Secretary of this Society, and desires to make formal expression of its appreciation of his untiring, devoted and eminently successful services as Secretary during the very important period of the Society's development from 1903 to 1911.

Resolved further, That this resolution and the accompanying report be spread upon the Minutes of the Society, and that a suitably engrossed copy be forwarded to Mr. Baxter with a letter of transmittal by the president, conveying the best of wishes from his fellow-members and their earnest hope for his speedy and complete restoration to health.

Very respectfully,

W. L. Capps.
J. W. Miller.
Herbert C. Sadler.

THE PRESIDENT:—Gentlemen, you have heard the report of the Committee. What is your pleasure?

MR. WALTER M. MCFARLAND, *Vice-President:*—I move the adoption of the report.

THE PRESIDENT:—Are you ready for the question? All those in favor please say aye; contrary minded, no.

The report is unanimously adopted.

THE PRESIDENT:—To suit the convenience of some of the authors of the papers, we have varied the program. The paper entitled "Economy in the Use of Oil as Fuel for Harbor Vessels," by Engineer-in-Chief C. A. McAllister, a Member of the Society, will now be read by Mr. McFarland.

MR. MCFARLAND:—I am sure that all of you who know him, would much rather have Captain McAllister here to read his own paper. His personality is altogether so delightful that we miss a great deal by his absence. However, he could not be here, and he asked me to read his paper, and I will do the best I can to fill his place.

ECONOMY IN THE USE OF OIL AS FUEL FOR HARBOR VESSELS.

By Engineer-in-Chief C. A. McAllister, Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

Heretofore it has not been usual to look for economical methods in the expenditure of public moneys, either Federal, State or municipal. Of late, however, it is quite pleasing to note that great attention is being paid to economy in all branches of the Federal Government. In none of these has better results been attained than in the Treasury Department, presided over by Secretary MacVeagh. Himself a successful business man before becoming a member of the Cabinet, he has brought with him and in an unostentatious manner has imbued his subordinates with the spirit of economy without impairment of efficiency.

A good example of an economy of this kind is the oil fuel apparatus recently installed on board the harbor tug Golden Gate, doing revenue cutter boarding duty at San Francisco, California. Some preliminary reports of the efficiency of this apparatus have already appeared in the daily press and in various technical journals. So many favorable comments have been received of these reports that the writer has taken the liberty of presenting the following more extended account to the members of this Society, in the hope that the data herein presented may be of value in the possible extension of this system to other harbor vessels.

An investment paying over one hundred per cent. in annual dividends would naturally appeal to any business man, and the data herein given will show how it has been accomplished in this particular instance.

The Golden Gate is a vessel of the ordinary harbor tug type, 110 feet long over all, 100 feet between perpendiculars, 20 feet 6 inches beam moulded, and a moulded depth of 12 feet $\frac{1}{2}$ inch amidships; the normal displacement being 220 tons. She is built of mild open-hearth steel throughout, and was completed in 1896 at a total cost of $50,000. Her propelling machinery consists of a water-tube boiler and a vertical, inverted, triple-expansion engine with cylinders of 13 inches, 21 inches, and $32\frac{1}{4}$ inches diameter, respectively, and a common stroke of 24 inches. Under maximum conditions it is capable of developing 550 indicated horse-power.

She is provided with two ordinary fore-and-aft coal bunkers in the boiler space, with a total capacity of thirty tons. The question of fitting this vessel for using oil fuel naturally arose several years ago upon the

development of the large oil deposits in California, and many steamers of all descriptions, employed on the Pacific Coast, were thus equipped. As the cost of transforming the coal bunkers into oil-tight tanks for fuel-oil was considered prohibitive in view of the age of the vessel, and the lack of funds for the purpose, the idea was temporarily abandoned. However, in the early part of 1910, it was found necessary to fit this vessel with a new boiler, and the thought then occurred to the writer that a limited oil system could be installed at a comparatively small cost. The duties of this vessel are almost entirely confined to San Francisco harbor and the waters adjacent thereto, so that at no time is she more than thirty or forty miles from her wharf. A scheme was therefore evolved of fitting a horizontal cylindrical tank under the deck beams in the fire-room space, as shown in the accompanying drawing. The result was that this tank having a capacity of 23 barrels, the oil pump, burners, etc., complete in all details, were fitted at a total cost of only $2,500.

The oil is obtained from a pipe line run to the end of the wharf immediately alongside the water hydrant, so that the labor of fueling and watering the vessel is reduced to a minimum; in fact the oil tank can be filled in ten minutes. This tank carries sufficient oil for ten days ordinary use, as the tug's duties are very intermittent and consist of running down to the harbor entrance and placing inspectors on incoming foreign vessels. For nearly nine-tenths of the time she must lie at the wharf, with steam up and be ready for an immediate call at any time a vessel is reported as coming into port. The great saving is therefore in the time that the vessel would ordinarily be under banked fires if coal was used. As soon as the run is over under present conditions the oil is, of course, shut off and practically no fuel is used when the cutter is not underway. In the summer months the oil can be shut off, the boiler closed up tight, a full glass of water pumped in, and with steam at 150 pounds at six o'clock in the evening there will be found ample pressure the next morning to start the oil pump, when steam at the working pressure can be raised in a few moments. In the winter season when it becomes necessary to use steam for the radiators, one burner partly turned on is found ample to keep up the pressure, and the additional fuel consumption for this purpose in 24 hours is found to average about one barrel.

There is nothing unusual about the apparatus employed, as it consists of a No. 10 S. & P. oil pump with the necessary heater, coil, governor, relief, gauge, tank, strainers, etc. There are three ordinary type burners, one to each furnace, which project about 12 inches beyond the door frame liners and are about 6 inches above the level of the grates, slanting slightly downwards.

One feature of this particular plant is that the coal-burning apparatus remains intact; the ordinary grate bars are fitted in place, but covered over with fire-brick. For purposes of ballast about ten tons of coal in bags are carried in the bunkers, so that if it ever becomes necessary to order the tug to some other port where oil is not obtainable, or if for any reason the oil supply should become exhausted, the change to coal burning could be made in a very short time.

The engineer's force when coal was used for fuel consisted of four men; with oil it is found that three men can easily perform the work, and consequently one man was transferred to another vessel to fill a vacancy. The saving in the wages, food, and clothing of the fireman thus dispensed with amounts annually to $674.

Strict account of all expenditures made on Government vessels are rendered each month, so that it is possible to submit the following tabulations (Table I) showing the comparative costs of fuel for periods of nine months; first with coal as fuel and second with fuel oil. The contract price of coal in San Francisco during the period covered by the table was $5.40 per ton of 2,240 pounds, and the contract for oil was made at a rate of $0.60 per barrel of 42 gallons.

Attention is called to the fact that the miles cruised during the period since the oil-burning apparatus was installed are not so great as for the corresponding period when coal was used; this was due to the decreased demands for the services of the tug and will not materially affect the general result.

The average saving in fuel cost per month for the nine-months period covered by the above schedule is $172.88; for a year at this rate it will be $2,075.26. This added to $674, the saving of expense by dispensing with one fireman, makes the total annual saving $2,749.26, which it must be admitted is a decidedly good showing for an original investment of only $2,500.

It is not, of course, to be contended that there would be such a marked saving at any port in the country as shown herein, for the high cost of coal and the low cost of oil in San Francisco are probably the extremes which would be met with at any of our large seaports. However, the saving would be sufficient in many harbors to warrant the necessary expenditure.

For example, if the Golden Gate were stationed in New York harbor, the following would be the results based on fuel expenditures for the nine-months period given above. The contract price for coal for revenue cutters in New York is $2.85 per ton, and fuel oil can be purchased at approximately $0.90 per barrel. The amounts of the fuel used are the totals from the tabulations:

TABLE I.

With coal.					With oil.					
Date.	Hours under-way.	Miles traveled.	Tons of coal used.	Cost of coal used.	Date.	Hours under-way.	Miles traveled.	Barrels oil used.	Cost of oil used.	Monthly saving.
October, 1909	101.50	875	49.0	$264.60	October, 1910	70.55	660	106.76	$64.06	$200.54
November, 1909	75.10	640	40.1	220.80	November, 1910	63.40	545	75.10	45.06	175.74
December, 1909	61.15	515	39.6	213.97	December, 1910	55.40	459	72.00	43.20	170.77
January, 1910	81.55	710	41.5	224.10	January, 1911	57.35	485	79.00	47.40	176.70
February, 1910	50.00	410	32.7	176.65	February, 1911	56.00	435	76.00	45.60	131.10
March, 1910	77.25	680	46.0	248.40	March, 1911	64.30	495	86.00	51.60	196.80
April, 1910	81.35	695	49.9	269.37	April, 1911	86.10	640	110.00	66.00	203.37
May, 1910	67.05	570	35.9	193.86	May, 1911	56.30	410	83.00	49.80	144.06
June, 1910	66.50	560	38.4	207.56	June, 1911	53.50	400	84.50	50.70	156.86

373 tons of coal at $2.85 per ton	$1,063.05
772 barrels of oil at $0.90 per barrel	694.80
Net saving on fuel (for 9 months)	$368.25
Net saving on fuel (for one year)	491.00
Add cost of one man's services (for one year)	674.00
Total annual saving by use of oil fuel	$1,165.00

Thus, even in New York where the prices of the two kinds of fuel are not at such variance, an expenditure of $2,500 in the manner described, would result in an annual dividend of over 46.6 per cent. on the investment.

Whether the substitution of oil fuel in the manner described would prove to be a good investment on an ordinary harbor tug engaged in long continued towing jobs is a matter of conjecture, but there is no doubt in the writer's mind as to the certainty of saving by the use of this method on all harbor vessels engaged in work of an intermittent character, of which, as we all know, there are many in all large seaports. There can be but little doubt of a great saving if it should be applied to the number of city fire-boats now in use in many of our harbors.

It is almost needless for me to dwell on the advantages other than monetary, which accrue from the use of oil as a fuel for steam vessels. The smoke nuisance is almost entirely abated; there are no ashes to handle; the fire surfaces of the boiler do not need such frequent cleaning; in fueling the ship much time is saved, as are also the attendant hard work and dirt which accompany all handling of coal; in fact most of the disagreeable features connected with work in the fireroom are eradicated.

While there is but little of value in this brief paper from a scientific standpoint, it is hoped that the facts detailed herein may be of some use to the members of the Society from the practical standpoint of saving in both money and needless work.

DISCUSSION.

THE PRESIDENT:—The paper by Captain McAllister, "Economy in the Use of Oil as a fuel for Harbor Vessels," is now open for discussion.

MR. JOHN REID, *Member:*—I agree with Mr. McFarland that this paper is of particular value, owing to the very accurate data which it gives us of an actual example

of a tug converted from a coal burner to an oil burner, but I think that one should use that data with caution in applying it to cases in which the working conditions are not similar. The economy effected is largely due, I think, to the cause given on page 180, namely, "For nearly nine-tenths of the time she must lie at the wharf with steam up and be ready for an immediate call at any time a vessel is reported as coming into port." That is a condition of affairs in which oil fuel possesses tremendous advantage, but you do not get that condition of affairs with the ordinary commercial tugs. I do not suppose you will get it in a New York tug, waiting for work, because they keep the steam up at full pressure all the time, and they are burning the fuel at an even and high rate, as they are working continuously through the day.

But there is another trouble that I see in this paper, and that is this—when you look at the Table I, you see that the tons of coal for hours underway, for October 1909, were 101.50, taking the first line, and that 49.0 tons of coal were used. That is about a half ton of coal per hour, or about twelve tons for the twenty-four hours. That is a very high rate of coal consumption, and I have noticed, in comparing results procured with coal and oil, how much one can do to improve the coal situation by a little care in the management of boilers, having furnaces to suit the coal, using forced draft, etc., which I presume this boat did not have.

We had a case not long ago where we wanted to decrease the dead weight of the boat, and we thought we could use oil, and do away with the weight of the bunkers carried, and tried it out. The boat was burning about seven tons of coal an average day, and that at $2.50 a ton, comes to something like $17.50. When we tried oil fuel, we found that we could only burn one and one-half tons, in order to keep under the coal price. I will mention a curious circumstance that most of you are familiar with, that the price of oil automatically rises—I do not know the reason why it is so—just under the figure at which you could use coal, and I notice that Captain McAllister, in his arrangement, has suggested that he might be able to convert back into a coal burner pretty quickly—that is a good provision—but it is unfortunate from his point of view, because the keeping of the fire bars and under-grate arrangements in the furnace is definitely a drawback in the oil situation. You will not get to-day, with an oil flame, unless it is properly distributed around the furnace, the greatest heating effect from over the whole furnace, and most people take out everything that prevents the circulation of the fire to and around the furnace, and if you cut out half of the furnace, in order to keep in the grate bars, you interfere with the efficiency of the oil-burning process.

Then as to the question of strikes or accidents. It happens to be our misfortune that we have to employ a class of men who are very troublesome, and those are the firemen. In the Lake trade, with which I have a good deal of familiarity, the firemen are an everlasting source of trouble and worry, and if you can cut the fireman out, it is worth your while to use oil, even if you have to pay more for it, both in first cost and also in the cost of the fuel from day to day.

This paper is certainly a step in the direction of oil burning, as regards modern

work, but I think one has to go a step farther. In order to get the full advantage of oil burning to-day, you have got to go to the oil engine. There is a paper coming up which will describe that subject on which I shall, perhaps, have something to say, but there is one thing I have found with the oil engine, however unreliable it may appear to be, the economy of consumption is something astounding, which you cannot realize until you try it.

However, to convert an old vessel into an oil burner, unless you have a very large margin of safety, especally if you are going to be cruising somewhere some day when you want to get oil cheaply and conveniently, and you cannot do it, is rather a dangerous game.

THE PRESIDENT:—Are there any further remarks upon this paper?

MR. EDWARD P. ROBINSON:—There is one thing that occurs to me in this connection. I think as a matter of fact that tow-boats about the size of the Golden Gate, referred to by the author lie at the dock a large portion of the time. That fact has led owners in many cases to give up the more economical compound condensing-engine, and go back to the old fashioned high-pressure non-condensing engine, which has no auxiliaries, because they claim that, while the boat is actually in use, the question of fuel economy is not so important as is the ability to stop all steam consumption while the boat is tied up at the dock waiting for a tow, and it is a fact that there are a good many boats of about this size that do that very intermittent work.

THE PRESIDENT:—Are there any further remarks upon this paper?

ENGINEER-IN-CHIEF MCALLISTER (Communicated):—I have read Mr. Reid's criticism with considerable interest. He inadvertently has fallen into error when he assumes that 49.0 tons of coal were used in the 101.50 "hours underway" during the month of October, 1909, and then by inference assumes that this boiler when using coal did not have proper care. Had his understanding been correct (and it is admitted that Table I is not very clear on that point) his criticism would have been well taken, but the fact is that 49.0 tons of coal is the total amount used under "banked fires" as well as "underway" during that month. It will therefore be seen that this is not a "high rate of coal consumption" by any means. Assurances are also given to Mr. Reid that as much care is given to the management of boilers using coal, in the vessels of the Revenue-Cutter Service, as is given to any vessels of similar type afloat.

THE PRESIDENT:—Mr. Reid called attention to a very peculiar thing, if it is a fact, and I have heard it too, that the price of oil seems to vary so as to keep it just within a certain point of the price of coal.

If there are no further remarks on this paper, with your permission I will have recorded a vote of thanks to Mr. McAllister for his admirable presentation of the subject contained in his paper. I take it for granted you will accede to that.

VICE-PRESIDENT MCFARLAND:—As Mr. Dickie, the author of the next paper, is not here, and as it is of the same general nature as the first paper on the program for to-day, the Secretary will now read paper entitled, "The Best Arrangement for Combined Reciprocating and Turbine Engines on Steamships," by Mr. G. W. Dickie, Member of Council, by title so that you may discuss it in connection with the paper on "The Parsons Marine Steam Turbine and its Application to Various Classes of Vessels," which is on the same general subject. The Secretary will read the paper by title.

Secretary Daniel H. Cox read the paper—"The Best Arrangement for Combined Reciprocating and Turbine Engines on Steamships," by Mr. G. W. Dickie, Member of Counsel, by title.

THE BEST ARRANGEMENT FOR COMBINED RECIPROCATING AND TURBINE ENGINES ON STEAMSHIPS.

By G. W. Dickie, Esq., Member of Council.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

It is by invitation of the Committee on Papers that I am presenting to the Society what I think should be the best arrangement of combined reciprocating and turbine engines on steamships. In accepting this invitation, I am well aware that the opinion I have reached, after much thought on the subject, is at variance not only with the opinion but also with the practice of some very eminent engineers, whose experience is much wider than mine. It is to be expected, therefore, that what I have to present will be challenged and declared entirely untenable. If I thought the members of this Society would agree with me in regard to anything I might present before them, I would not take the trouble to present this paper. I am still Scotch enough to enjoy discussion and criticism, especially when administered with the good feeling that prevails in this Society.

While the subject of this paper is "The best arrangement of combined reciprocating and turbine engines on steamships," it does not follow that the arrangement proposed by the author is the best. The Committee on Papers, I presume, would like to have the question discussed and it is quite possible that the presentation of the very worst arrangement may enable the Society to discover the best.

Among the many benefits to steam engineering, that have resulted from the introduction of the modern forms of the steam turbine as a rival of the highest developed type of reciprocating engine, none is of more importance than the wider knowledge among engineers, that has come with the rapid introduction of the steam turbine giving rise to conditions that must be met and satisfied by the reciprocating engine that is to use steam economically. Experience with the turbine has emphasized, not only the weak points of the reciprocating engine, but at the same time furnished like evidence of its own weak points.

It so happens that both types of steam engine have an economical and a wasteful end. In the turbine the steam begins its work in the wasteful end and finishes in the economical end, while in the reciprocating engine this is reversed. This condition, in the reciprocating engine, is largely due to functional causes. The alternate heating and cooling of the cylinders, caused by the drop in temperature as the steam expands and produces work—the difference in temperature being much greater in the low pressure than in the high pressure end—and the consequent condensation due to the heat ab-

stracted from the steam to replace that lost in the low pressure cylinder during the exhaust stroke. The thermal lines cross each other twice every revolution.

The turbine engine escapes this loss because the steam is continually moving in one direction on its way to the condenser, and the cylinder, or casing, and the rotor maintain a temperature that corresponds with that of the steam at any point on its way to the condenser. Mechanically, however, the turbine is defective, as a certain amount of clearance must be allowed between the tips of the rotor blades and the casing and also between the tips of the guide blades and the rotor. As these blades, at the high pressure end, are very short and the clearance has to be as great there as elsewhere, the free passage for steam at the high pressure end of the engine is quite considerable, especially in the marine type where the rotors are of greater diameter and the area of clearance correspondingly greater. Where the blade is only about one inch in length and with, say .05 inch or .06 inch clearance, we have over ten per cent of clear space for the steam to pass without doing work. At the low pressure end, however, where the blades may be ten inches long, the same clearance would only be one per cent. The escaping steam at the high pressure end is of course forced to do some work as its volume expands and the length of blade increases.

I have just been trying to compare the data on a set of indicator cards from a triple expansion marine engine, the aggregate horse-power being 5,600 divided as follows: high pressure cylinder 1,886 horse-power, intermediate pressure cylinder 1,874 horse-power, and low pressure 1,840 horse-power—these are sufficiently close to say that the power is divided equally among the three cylinders—with data from a marine turbine set consisting of a central high pressure and two wing low pressure turbines giving 5,500 shaft horse-power, also practically divided evenly between the three shafts. No superheating in either case.

In the reciprocating engine, the first stage or one-third of the total horse-power, is obtained by a drop in the pressure from 180 pounds absolute to 70 pounds absolute, being a drop of 110 pounds, corresponding to a drop in temperature from 372.9 to 302.9 or 70 degrees.

In the turbine engine, the first stage or one-third of the total horse-power is obtained by a drop in the pressure from 175 pounds absolute to 35 pounds absolute, being a drop of 140 pounds, corresponding to a drop in temperature from 370.8 to 259.3 or 111.5 degrees.

In the reciprocating engine, the second stage or one-third of the total horse-power is obtained by a drop in the pressure of 70 pounds absolute to 25 pounds absolute, being a drop of 45 pounds corresponding to a drop in temperature from 302.9 to 240.1 or 62.8 degrees.

In the reciprocating engine the third or last stage is obtained by a drop in the pressure from 25 pounds absolute to 2 pounds absolute, being a drop

of 23 pounds corresponding to a drop in temperature from 240.1 to 126.26 or 113.84 degrees. The aggregate drop in pressure for the second and third stages or two-thirds of the total horse-power, is from 70 pounds absolute to 2 pounds absolute, a drop of 68 pounds corresponding to a drop in temperature from 302.9 to 126.26 or 176.64 degrees.

In the turbine the second or last stage, or two-thirds of the total horse-power, is obtained by a drop in the pressure from 35 pounds absolute to 1 pound absolute, being a drop of 34 pounds corresponding to a drop in temeprature from 259.3 to 102 or 157.3 degrees.

These pressures and temperatures are not given for the purpose of making any comparison between the economic performance of the reciprocating engine and the turbine, for as a whole their economy was practically the same. The consumption of fuel of like quality was practically the same per horse-power with the advantage in favor of the turbine as between shaft and indicated horse-power, the volume of steam passing through the cylinders was practically the same as that passing through the rotors, yet 1,886 horse-power, slightly over one-third of the total, was developed with a drop of pressure of 110 pounds, corresponding to a drop in temperature of 70 degrees, consequently the mean temperature of the high pressure cylinder, with its small surfaces, would be about 35 degrees below that of the entering steam. In the second stage, 1,874 horse-power, slightly more than one-third, was developed with a drop of pressure of 45 pounds, corresponding to a drop in temperature of 62.8 degrees, consequently the mean temperature of the intermediate pressure cylinder would be about 31.4 degrees below that of the entering steam. In the third stage, however, 1,840 horse-power, 26 less than one-third, was developed with a drop of pressure of 23 pounds, corresponding to a drop in temperature of 113.84 degrees, consequently the mean temperature of the low pressure cylinder would be 56.92 degrees below that of the entering steam, which, taken in connection with the larger surfaces, accounts for the great loss in the last stage. The intermediate cylinder being steam jacketed would indicate that considerable re-evaporation took place in that cylinder.

It is unfortunate that, if the exact point was known in the expansion of steam where on the one side the economy would be with the reciprocating engine and on the other with the turbine, yet that point might not be the best place to make the division. There are other matters such as maneuvering with reciprocating engines, propeller design and desirable arrangement in the available engine room space, that may render the best arrangement for steam economy not the best for general economy.

I believe that the best result in steam consumption could be gained from having the terminal pressure for the reciprocating part of the engine power at or about 30 pounds absolute, or a little above the usual low pressure

receiver pressure in triple expansion engines. This is very far from that usually adopted as the best arrangement, everything considered.

The arrangement that has found favor with those responsible for the most important installations of power on board ship, where the two types of engine have been combined, has been that in which the steam has been expanded in the reciprocating engine down to a pressure of 9 or 10 pounds absolute. This would give a drop in temperature in the low pressure cylinder of about 62 degrees, say a mean of 31 degrees below the temperature of the entering steam. This, I think, is far below the line where the economy of the turbine is superior to that of the reciprocating engine and is undoubtedly the result of accepting as best the arrangement of two sets of reciprocating engines and one exhaust turbine between, the new White Star liners being notable examples of this arrangement. For very large installations of power there are several important advantages that attach to this arrangement. The size of the reciprocating engines is thus kept within reasonable limits. The maneuvering power is eighty per cent. of the total. A break down of the turbine engine leaves the whole maneuvering power intact, while a breakdown in one of the reciprocating engines still leaves seventy-five per cent. of the propelling power intact and forty per cent. of the maneuvering power available. There would also be what advantage can be claimed for twin screws for maneuvering.

Notwithstanding these important advantages claimed for the arrangement of two reciprocating engines and one turbine, I believe that better results, with installations up to 20,000 horse-power can be secured by having one reciprocating engine on the center line delivering steam to a turbine on each side at about 30 pounds absolute. This is slightly below the pressure that, in the regular three turbine set, the steam is usually delivered to the low pressure turbine. This would admit of the center line engine developing about 40 per cent. of the total power and, when exhausting straight to the condenser, at least 60 per cent. of the full power. The larger and most effective propeller would be on the center line where its efficiency would have the best propelling effect. The smaller side propellers would not require so wide projections from the side of the ship and would thus cause less disturbance to the water in the after run. With the large propeller in the center, the side propellers could be run at a higher number of revolutions than would be advisable for the center propeller were it turbine driven. This would permit of the turbine rotors and casings being of a moderate diameter. In a 20,000 horse-power set of engines, with the center line shaft making say 78 revolutions, I would have the side shafts running about 400 revolutions which would give a diameter of about eight feet to the rotor. This would enable the turbines to be placed alongside the reciprocating engine in any merchant ship having that amount of power.

With the reciprocating engine closing its work with a terminal pressure of 30 pounds absolute, a simple compound engine would give satisfactory results. Where the total power was to be above 8,000, I would make the reciprocating engine with two high and two low pressure cylinders, the high pressure cranks being 180 degrees apart and the low pressure cranks 180 degrees apart, each pair being 90 degrees apart, this would produce a well-balanced engine. Both pairs of cylinders would have piston valves. The valves for each pair being arranged so that one would take steam on the outside of the valve and the other on the inside. This would enable the valves for each set of cylinders to be operated by one valve gear, making an exceedingly simple marine engine. By a proper arrangement of exhaust from the low pressure cylinders, only one change valve would be necessary. This would be operated by a direct steam cylinder, controlled by a hydraulic cylinder and piston so that the movement might be as slow as required. No steam jackets would be needed on the cylinders. The exhaust pipes, however, from the low pressure cylinders to the turbines might be jacketed with advantage.

In such an arrangement there need be no objection to operating the air pumps, of which there would be two, through levers worked from the crossheads of the low pressure cylinders. These pumps would be placed so that the foot valves would be as low down as possible, the channel way being in line with the lower face of the bed plate so as to be below the lowest part of the turbine casings, it being important to have them thoroughly drained. The dry air pumps should be operated in the same manner as the wet air pumps, being placed above the operating levers in a direct line with the wet pumps. The writer, however, would prefer to have the air pumps independent as shown on the sketch arrangement illustrating this paper, which would simplify the main engine and enable the turbines to be run without the reciprocating engine being in use. The feed pumps would be operated independently and thus remove another source of trouble from the main engine. In nearly all cases there would be room to install the main condensers on the outboard side of the turbines, so placed as to have the exhaust passage in the middle of the length of the condenser. The channel ways or connections to the wet air pumps would pass through the lower part of the turbine casings and connect direct to the lower chambers of the pumps. As the turbines would not be as long fore and aft as the reciprocating engine, there would be plenty of room for all engine room auxiliaries.

An outline of how such an arrangement would be installed for say 20,000 horse-power will accompany this paper. The dimensions of the various parts have not been worked out to meet any specific conditions, or to any refinement of accuracy, but are near enough to show how such an arrangement when perfected would look in place, the ship having a moulded breadth of 66 feet.

This arrangement admits of a cooler engine room than can be obtained where the hottest parts of the machinery are in the wings and, in most cases, under deck. In the arrangement proposed by the writer the hottest parts of the machinery are directly under the casing that leads up through all the decks to the open air above.

There are certain objections which will be brought against my arrangement and some of these are important and have been carefully considered. It may be asked, why sacrifice the maneuvering power of two propellers on reversing engines for that of one? In reply to this it is claimed that the advantage of a simpler and cheaper arrangement with the most effective propeller on the center line of the ship and the promise of better economy, should outweigh any possible advantage for maneuvering that the twin screw has over the single screw ship. It is quite possible that this advantage may be over-rated. The writer, from his office window, has the opportunity to watch the docking of two steamships once a week. They are sister ships in every respect except that one is a single screw while the other has twin screws. Each vessel is of 5,000 horse-power and 400 feet long on the water line. The dock that these vessels land at is across the tide which runs either one way or the other with the flood or ebb. The writer is interested in these vessels, both having been built under his supervision, and yet after careful observation, extending over three years, he has not been able to observe any marked advantage that the one has over the other in making a landing at the dock, no assistance is ever required by either of them. Two days ago he timed the single screw vessel and found that the time consumed from being abreast of the end of the dock to being moored alongside was just 6.5 minutes. In a larger ship, the turning effect of running the screws in opposite directions would be still less than in the ships mentioned above. The backing power of the single large propeller on the center line when the engine exhausts to the condenser would be ample for all purposes.

Another objection that might be raised to the arrangement advocated by the writer, is that a breakdown of the reciprocating engine would deprive the ship of any backing power. This objection must be admitted, yet from the simple construction of the proposed reciprocating engine, a breakdown involving the stopping of the engines for good seems rather a remote possibility and, if it should happen, the turbines could keep the vessel going ahead until she could arrange by wireless for assistance in making port.

These are the two principal objections that can be advanced against the arrangement that the writer proposes, while, if he is right in the claim that the turbine can show a higher efficiency than the reciprocating engine to a point much higher in the expansion curve than 9 or 10 pounds absolute, then the arrangement he proposes would give a better combined economical

result and be simpler and less expensive. The chances for air leaks, where the reciprocating engine delivers the steam to the turbines at 30 pounds absolute, is reduced to one stuffing box at the condenser end of the low pressure turbines while, in the case of two sets of reciprocating engines exhausting to one turbine at 9 or 10 pounds absolute, there are always possible air leaks at both ends of the turbine and at the stuffing boxes of both low pressure cylinders of the reciprocating engines.

In one arrangement proposed by the writer, the air pumps, both wet and dry, are operated from the low pressure cylinder crossheads. This might be objected to as not providing any means for maintaining a vacuum should the reciprocating engine be disabled. The object in making the air pumps part of the main reciprocating engine is simply one of first cost and some advantage in economy of steam and of work in caring for the pumps. The writer has forestalled this objection and prefers the independent pumps as an additional security against any failure of the reciprocating engine. Of course independent air pumps can be installed, in which case they should exhaust into the turbine steam chests. Our sketch plan shows this arrangement.

In a paper read by A. C. E. Rateau at the Jubilee Meeting of the Institution of Naval Architects, July 5 of this year, which has just reached the writer this morning, July 20, there seems to be something that would indicate that the arrangement proposed in this paper had been considered by Professor Rateau. He says that, "In 1906 we fitted the French Destroyer Voltigeur with an improved arrangement of engines. The power is distributed on three shafts (center shaft reciprocating engine with turbines on wing shafts). Up to a speed of 20 knots, the reciprocating engine exhausts into the turbines but above that speed the engines become independent. We could therefore have realized a perfect engine up to a speed of 20 knots if the reciprocating engine and the turbines had been designed solely with the view of obtaining better results by working by stages, but instead of this, they were designed more particularly with the object of obtaining the maximum efficiency at full power." In other words, the Professor, by providing a third condenser for the reciprocating engine to exhaust into at full power, added to the power developed at the expense of the lost economy in the low pressure end of the reciprocating engine and in the high pressure end of the turbine and, even when exhausting from his reciprocating engine into the turbines, he lost in economy by using low pressure steam in turbines designed to be operated by steam direct from the boilers.

In utilizing the expansion in reciprocating engines down to a pressure of say 9 pounds absolute, we must have cylinders of large dimensions subject to marked changes in temperature every revolution, involving large losses due to condensation combined with large frictional losses causing a

great curtailment in the theoretical gain due to the expansion; on the other hand by turning the steam over to the turbines at a pressure and temperature that insures a more economical continuation of efficiency in the power developed, we thereby succeed in obtaining the very best possible out of each type of engine.

All this, of course, has been considered by the able engineers who have designed the important installations of combined reciprocating and turbine engines that have been fitted to equally important additions made lately to the great steamships of the world. The writer thinks, however, that the desire to hold on to the advantage claimed for the twin screw ship in maneuvering and the ability to continue a voyage with one engine disabled, may have had much to do with determining the arrangement of these great combinations of reciprocating and turbine engines. The installation on the Olympic, for instance, can hardly be called a combination of reciprocating and turbine engines, but rather a splendid example of reciprocating engine practice with a turbine in the exhaust to utilize the last stage of expansion which the low pressure cylinder could not manage with any efficiency.

In the arrangement proposed in this paper, there is no sacrifice of go ahead power with either the reciprocating engine or the turbines disabled, but only a sacrifice of backing power should the reciprocating engine be out of commission. The question is one that ought to form a good subject for discussion by this Society.

The President:—Yesterday afternoon the paper entitled, "The Best Arrangement for Combined Reciprocating and Turbine Engines on Steamships," by Mr. George W. Dickie, Member of Council, was read by title. We will now take up at this time the paper entitled "The Parsons Marine Steam Turbine and its Application to Various Classes of Vessels," by Mr. E. H. B. Anderson, Member. These two papers will be discussed together. I will ask Mr. Anderson to present his paper.

Mr. E. H. B. Anderson:—Mr. President and Gentlemen, the object of this paper is to put before the Members of this Society some of the various arrangements of Parsons Turbines, both in the present vessels and in those built in the past. I will not go over the paper in detail, for the reason it would probably take up too much time, and I think you all have copies of the paper.

One of the main points I want to bring out is, that in the Parsons Turbine there is no one standard type of arrangement, but that Sir Charles Parsons himself has invented special features in his machinery designs which are arranged to suit the requirements of each type of vessel.

Mr. Anderson then presented the paper.

THE PARSONS MARINE STEAM TURBINE AND ITS APPLICATION TO VARIOUS CLASSES OF VESSELS.

By E. H. B. Anderson, Esq., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

The object of this paper is to put before the members of this Society some of the various arrangements of turbine machinery in past and present vessels, which are fitted with Parsons turbines of the reaction type. Dealing with the well known pioneer vessel Turbinia it is of interest to note that in torpedo boats and small fast steam yachts of this type, a similar arrangement of machinery is still installed and there are about 40 such vessels at sea and in addition 10 are under construction at the present time for the Spanish Navy. In the Turbinia, the astern turbine is in a separate casing and no cruising turbine was fitted.

This arrangement combines simplicity with extreme lightness of parts and good economy over a very wide range of power. (Plate 95.)

In the earliest turbine destroyers, Viper, Cobra and Velox, four shafts were fitted, having two sets of independent ahead turbines, consisting of two high pressure and two low pressure with astern turbines on inboard shafts only.

This design was followed in the next destroyers by the standard three-shaft arrangement to which was added two cruising turbines in series, arranged at forward end of each low pressure turbine. (Plate 96.)

There are about 100 vessels constructed with such an arrangement having shaft horse-powers varying from 7,000 to 20,000 and speeds from 26 to 34 knots.

In the United States Navy there are 15 of this type at sea and four being built, all of which have speeds of 29 knots and upward.

In the French destroyers having the usual three shaft arrangement only one cruising turbine is fitted, and the machinery is arranged in two compartments.

For small fast cruisers, the three-shaft arrangement has been found very satisfactory, and this design was adopted in H. M. S. Amethyst and in the first turbine warship, Mogami, built for the Japanese Navy, and in two scouts completed for Brazil in 1909. No cruising turbines were installed in the ship built for Japan.

Three small cruisers of the three-shaft type are at present under construction for the Chinese Navy. In these installations no separate cruising turbines are being fitted, but the high pressure turbine has been arranged with an additional stage to improve the economy at cruising speeds and at full power, bye-pass valve arrangements will be made use of admitting steam to the second stage. (See Plate 99.)

Among the smaller cruisers and scout cruisers, the four-shaft arrangement has been adopted largely.

In England there are 14 vessels of this type at sea, some of which have cruising turbines in parallel, but in the latest design the machinery arrangement is similar to battleship and cruiser practice. Two are under construction for the Australian Colonies. The first German turbine cruiser Lubeck had such an arrangement and three others have since been completed for the same Navy.

A similar design was adopted in U. S. S. Chester, the first Parsons turbine warship in the United States Navy. (Plate 97.)

In the case of the large experimental turbine destroyer H. M. S. Swift the machinery was arranged on four shafts with the turbines in two engine rooms and on trial this vessel made an average speed of about 35.25 knots.

Dealing with battleships and cruisers of the Dreadnought type, four shafts are fitted, which are driven by two independent sets of ahead turbines consisting of two high pressure on outboard shafts and two low pressure on inboard shafts. Two cruising turbines are arranged in parallel at forward end of each low pressure turbine. All shafts are arranged with astern turbines, which are in two sets. Each set consists of a high pressure and low pressure turbine respectively. (Plate 98.)

In the latest ships of this type, cruising turbines have been dispensed with, and although it was recognized that the addition of cruising turbines improved the economy to a large extent, the complication together with the fact that such turbines are often running idly, decided against installing them in ships of this type, especially where cruising turbines are fitted in parallel.

The saving in weight, by omitting cruising turbines, was not made use of in cutting down the machinery weights, but the main turbines were increased in size so as to improve their efficiency, and at the forward end of each high pressure ahead, an additional expansion was fitted which is used when cruising, and for full power conditions bye-pass valve arrangements are made use of. (Plate 99.)

Five vessels of this type have completed all trials most successfully, four of which are battleships and one a battleship cruiser. Twelve additional ships of a similar type are now under construction in England, having speeds

varying from 21 to 28 knots, one of which is being built for the Australian Navy, and another, the money for which was sent as a gift to the British Government by New Zealand.

In the United States, four battleships are being installed with Parsons turbines and of which the Utah and Florida are in commission. The Wyoming and Arkansas are launched and both will be completed next year.

The main difference in the machinery lay-out of these ships compared with those of the Dreadnought type, is that the cruising turbines are arranged in series instead of in parallel. (Plate 100.)

In France, six battleships with arrangemnts of machinery similar to U. S. vessels have completed trials; two more are in an advanced state of construction and contracts have just been awarded for two others. All of these vessels have four-shaft arrangements of turbine machinery.

In Germany, the cruiser Von der Tann has given splendid results in commission and on trial made a speed of 27.63 knots. This ship has been followed with the cruiser Moltke which has made a speed of about 29 knots on a preliminary trial. There are three others under construction, which have four shafts, with the turbines arranged in series. In addition three battleships are being built, these ships having triple screws and turbines of the Parsons type, but with details special to the German Navy.

In Italy, there are at the present time four battleships under construction to be driven through four shafts.

In Russia, four large battleships are in course of construction having turbines arranged to drive four shafts.

In Austria, two battleships are in construction and a third has just been ordered, which will have four shaft arrangements of turbines.

In Spain, three battleships having speeds of 19½ knots are in course of construction. No cruising turbines are to be fitted, but one high pressure and one intermediate pressure on separate shafts take the place of the usual two high pressure turbines, and the intermediate pressure is arranged to divide its exhaust steam into two low pressure turbines arranged on the outboard shafts. (Plate 101.)

Japan has just ordered a large battleship cruiser, which is being built at Barrow, England. This vessel will have a high speed. Three others are to be built in Japan and will be fitted with turbines of the Parsons type, driving four shafts.

Three battleships have been ordered for Brazil, Chile, and Turkey, respectively, and all are to be fitted with four shafts.

The Brazilian naval authorities decided to fit turbines in their battleships after the success of the scouts.

In the mercantile marine, the three-shaft arrangement of turbine machinery similar to that installed in the first ship, the King Edward, is still used in almost all ships, except those of very large power. (Plate 102.)

This ship has been in regular service now for eleven seasons and is giving splendid results both as regards speed, economy and small amount of upkeep and repairs.

There are upward of 75 ships at sea fitted with similar installations, having speeds varying between 17.0 and 25 knots.

The pioneer liners Victorian and Virginian have the standard three-shaft installation, and these ships are maintaining speeds of $16\frac{1}{2}$ to 17 knots on round trips across the Atlantic. On the Pacific Ocean, the Japanese vessels Tenyo Maru and Chiyo Maru hold all speed records and can average about 20 knots.

Among other well known ships of this class may be mentioned the following:

	Knots.
Queen	21.73
Onward	22.53
Manxman	23.14
Viking	23.53
Ben-my-Chree	25.0
Jan Breydel	24.30
St. George	23.0
Carmania	20.0
Newhaven	23.85

In 1905, a two-shaft arrangement of machinery was installed in the steam yacht Narcissus.

In this installation, the two ahead turbines are arranged in series and an astern turbine is fitted to each shaft.

Pipe and valve connections are arranged so that the high pressure exhaust steam can pass direct to the condenser, and a live steam connection is fitted to the low pressure turbine, so that the vessel can be maneuvered similar to an ordinary twin screw reciprocating engine installation. (Plate 103.)

The first vessel built in the United States fitted with Parsons turbines was the Governor Cobb, having a speed of 18 knots. This vessel was followed by the Yale and Harvard with speeds of 21 knots. Another vessel, the Old Colony, has a speed of 19 knots. All these ships have the regular three-shaft turbine arrangement with two condensers. The Camden and Belfast are smaller vessels than the above and have speeds of 19 knots. The turbines in

these ships are arranged similarly to the above, but with the exception that one condenser is fitted instead of two. This is fitted between the low pressure turbines, both of which exhaust into this condenser placed over the high pressure turbine shaft line, the high pressure turbine being pushed forward to clear it. This change reduces the number of auxiliaries for only one air and circulating pump are in use, which means a saving in steam consumption and fewer auxiliaries to keep in order.

The Cunard liners Lusitania and Mauretania have four-shaft arrangements of turbines which consist of two independent sets. Each set is composed of one high pressure and one low pressure on separate shafts and similar to the usual battleship arrangement. In these ships separate astern turbines are fitted to the inboard shafts only, and of ample power to allow these ships to be maneuvered easily. These ships hold all records on the Atlantic and easily maintain $25\frac{1}{2}$ knots with fair weather conditions, the turbines making about 190 revolutions per minute.

A modified arrangement of turbines has been adopted in the French liner France, now nearing completion, which will further improve the economy as the turbines are arranged in series similar to the Spanish battleships. It is expected that this ship will have a speed of 23 knots at sea.

A similar arrangement of machinery is being adopted in the new Cunard liner Aquitania now under construction on the Clyde.

The Canadian Pacific Railway Co. and the Allan line have also under construction two large liners for the North Atlantic trade, and these ships are being fitted with an arrangement similar to the France.

In Germany there are under construction for the Hamburg-American line, two large vessels with four-shaft arrangements of machinery of the Parsons type.

The combination arrangement of turbines and reciprocating engines has also given good results.

This was first carried out in the destroyer H. M. S. Velox completed in 1903, in which two sets of twin engines were arranged at forward end of the low pressure turbines on inboard shafts and connected to exhaust into the high pressure turbines on outboard shafts. This was done to improve the economy up to a speed of 12 knots, above which the engines were disconnected, and it proved very successful.

In 1908, the New Zealand S. S. Otaki was installed with a three-shaft arrangement of machinery.

The wing shafts were driven by triple expansion reciprocating engines, arranged to exhaust into a low pressure turbine on center line of ship.

This ship was followed with the Laurentic having a similar arrangement

to the Otaki, and the decision to install this system in the White Star liners Olympic and Titanic was based on the successful results obtained with the Laurentic. (Plate 104.)

The Olympic has now made four round trips and the designed speed of 21 knots has been exceeded by ½ knot on service and with a low coal consumption.

The low speed French Transatlantic liner Rochambeau has a combination arrangement of machinery driving four shafts. In this installation, two sets of reciprocating engines are installed on the inboard shafts and the exhaust steam from each is passed into low pressure turbines arranged on the outboard shafts. This vessel has completed her trials very successfully and will shortly be put in service. Two ships with similar installations have just been put in hand to the order of Spanish shipowners. The Orient Line has also a large vessel in course of construction for the mail service between England and Australia, and having an installation similar to the previous three-shaft ships. At the present time there are 12 vessels completed and in course of construction having installations of this type. The American steam yacht Vanadis represents an alternative arrangement of a reciprocating engine and low pressure turbines. In this case there are three shafts, the center one being driven by a triple-expansion reciprocating engine, arranged to exhaust into low pressure turbines on the wing shafts. This installation was the subject of a paper read by Mr. Clinton Crane before the members of this Society in 1910.

The first application of a geared turbine was made by the Parsons Marine Steam Turbine Co. in 1897.

This installation was made for a 22-foot launch and consisted of one combined ahead and astern turbine, coupled to a pinion which was arranged to drive two gear-wheels connected to two shafts. In this case single helical gear was used.

In 1910 the S. S. Vespasian was fitted with a geared installation of turbines. This ship was originally fitted with one triple expansion surface condensing engine.

After carrying out a series of trials with this engine, the engine and condensing plant was taken out and in its place two fast running turbines, arranged in series and each driving, by means of a pinion, a double helical gear-wheel connected to the line shafting. It should be mentioned that the original propeller, line shafting, and thrust-block were left alone. This ship has now been in regular commission for 18 months giving splendid results, and absolutely no trouble has been experienced with the gearing, although the vessel has steamed about 32,000 knots. Further, it is of interest to note that there is no appreciable wear on the teeth of either pinion, and the original pair being still in use. (Plate 105.)

At the present time, two fast destroyers are nearing completion in England having geared turbine machinery driving two shafts. Two Channel steamers for the London and South Western Railway Company are also under construction. These ships will have two shafts, each shaft being driven by two fast running turbines in series connected to a double helical gear-wheel through pinions. (Plate 106.)

With regard to the question of multiple shafts, the present tendency among certain naval authorities is to cut down the number of shafts and turbines in vessels of the destroyer classes. A difference of opinion appears to exist as to whether two, three or four shafts, are most suitable from an economical and a practical point of view.

The builders of the Curtis, the Zoelly and similar types of turbines favor two-shaft installations, although in three large warships which have Curtis turbine machinery, three shafts have been adopted.

In a two-shaft arrangement of turbine machinery, a slightly better propeller efficiency may be obtained as compared with three or four-shaft installations, but the fact should not be lost sight of that propeller efficiency has to go hand in hand with turbine efficiency, and increased propeller efficiency can only be obtained by reducing the revolutions with a certain sacrifice in turbine efficiency.

There is a great deal to be said in favor of the distribution of the total power over several shafts, and the system of placing the turbines in series not only reduces the weight of the machinery and increases the propulsive efficiency of the steam, but improves the conditions for examination and overhaul carried out on board ship.

Further, by this subdivision of power over three or four shafts the turbines are much smaller, the weights to be dealt with are considerably less, and the work of opening out is greatly facilitated.

Contracts have recently been awarded for eight destroyers in this country, which are to be fitted with twin screws driven by turbines. In addition, all these vessels are being installed with two sets of reciprocating engines for cruising speeds up to $15\frac{1}{2}$ knots. These engines are arranged to exhaust into the turbines up to this speed, above which they will be disconnected.

Two of these ships have turbines of the Parsons type, similar to the arrangement in the steam yacht Narcissus (Fig 9, Plate 103); with the addition of a compound reciprocating engine at the forward end of low pressure turbine shaft for cruising speeds up to 16 knots.

At the present time there are only two battleships being constructed with twin sets of reciprocating engines, namely the U. S. S. New York and U. S. S. Texas.

It is not my purpose in this paper to describe at any length the arrangements of the engine room bulkheads and the subdivision of the machinery space.

In the three-shaft arrangements, both in merchant work, torpedo boats, destroyers, and including small cruisers of this type, the engine room is generally contained in one compartment having the turbines, condensers, and the various auxiliaries.

In the first vessels of the Dreadnought type, including the United States ships, the turbines and auxiliaries are arranged in one athwartship compartment divided along the center line of ship by a fore and aft bulkhead.

In the latest ships, the machinery is arranged in three compartments, in which both low pressure ahead and astern turbines are in one compartment, while the high pressure ahead and high pressure astern turbines are in separate compartments at the sides. The middle compartment contains the starting valves, condensing plant and various auxiliary machinery.

Arrangements are also made so that in case the wing engine rooms are flooded, the high pressure turbines can be shut off and direct steam connections used to each low pressure turbine, both ahead and astern. In the case of the Cunard liners Lusitania and Mauretania, the turbines are arranged in three compartments similar to the foregoing installations, both condensers in a separate water-tight room aft of engines and air and circulating pumps farther aft in two compartments.

As regards the steam consumption of turbine machinery, in the Turbinia the measurements figure out giving a water rate of about fifteen pounds per horse-power, all purposes at full power. In H. M. S. Amethyst the water rate in pounds per horse-power for all purposes at full power averaged 13.60 pounds. This agrees very closely with a figure of 14.0 pounds per shaft horse-power which was obtained with United States destroyers.

In battleships of the Dreadnought type, the water consumption in terms of shaft horse-power of main engines averages about 13.0 pounds for turbines only.

In large cruisers of the Indomitable type, the consumption for turbines only averages about 12.0 pounds per shaft horse-power.

In ships of the mercantile marine, the steam consumption of the turbine machinery for all purposes in terms of shaft horse-power of main engines averages about 15 pounds and in large installations such as the Mauretania about 14 pounds.

In vessels fitted with a combination system of reciprocating engines and low pressure turbines, a saving in coal consumption of about 12 per cent. is made, compared with similar ships having quadruple expansion reciprocating engines only.

In a battleship or cruiser installation an arrangement of geared cruising turbines would effect a saving of at least 20 per cent. at a cruising speed of 12 knots, this comparison being made with an installation having direct coupled cruising turbines.

A further increase in economy can be obtained by increasing the coefficients of the turbines. This would improve the results without any increase of machinery weight, due to a saving in the boiler-room installation.

A further economy of steam consumption is realized by arranging to pass all available auxiliary exhaust steam at suitable stages into the turbines instead of passing this direct to the main condensers.

In 1905 the total amount of Parsons turbine machinery of the marine type completed, amounted to about 270,000 horse-power.

At the present time the total horse-power completed, and under construction amounts to approximately 6,400,000, of which about 5,300,000 is to be fitted in warships; of this total 1,900,000 horse-power has been ordered during this year.

In the German Naval Programme of this year a total shaft horse-power amounting to 281,000 is being installed in ships fitted with Parsons turbine machinery, being 58 per cent. of the total ordered this year.

DISCUSSION ON THE DICKIE AND ANDERSON PAPERS.

THE PRESIDENT:—Gentlemen, you have heard the paper on "The Parsons Marine Steam Turbine and its Application to Various Classes of Vessels." Is there any discussion on the paper? You will also recall that discussion is now in order on the paper entitled, "The Best Arrangement for Combined Reciprocating and Turbine Engines on Steamships," by Mr. Dickie.

MR. R. C. MONTEAGLE, *Member:*—Mr. Dickie's paper is interesting and timely, but I believe there are several points which are open to serious criticism.

First, the proposal to make the center engine a 4-cylinder compound engine, instead of a 3-cylinder, or possibly a 4-cylinder triple expansion engine. Either of these types is more economical than the 4-cylinder compound—whether exhausting into a condenser at 8 pounds absolute pressure, or into a turbine at 30 pounds absolute pressure. The condition necessary to such economy being a mere increase of initial pressure. The reason for this additional economy being in the lesser amount of pressure or heat drop between the cylinders.

Second, I do not think it necessary nor advisable to sacrifice the backing feature in the turbine, and such an arrangement should, I believe, be prohibited as a source

of unnecessary danger to vessels so arranged, and to other vessels which may be near them. The author disposes lightly, of "a breakdown of the reciprocating plant, involving the stopping of the main engine for good," by stating that it is a remote possibility. We know that such accidents have occurred in the past, and doubtless will in the future. Accidents generally happen unexpectedly, and though seldom involving the stopping of the engine "for good," still long enough to inflict damage and possible death, or serious financial injury. The turbines should be fitted to back as well as go ahead.

Third, the proposed arrangement of combination valves for high pressure and low pressure cylinders, is not desirable, involving as it does, an exceedingly heavy cumbrous valve with correspondingly heavy gear to operate it and the consequent inertia due to these heavy working parts. This arrangement would be favorable to possible breakdown of these parts, in my opinion, and when such breakdown did occur, would inevitably shut the engine down "for good." Should a breakdown occur with the triple expansion arrangement, a rapid change would convert the engine to compound.

Mr. Luther D. Lovekin, *Member:*—Mr. President and Fellow Members, I have read Mr. Dickie's paper with great interest, as it is a subject which I have been giving considerable attention. Apart from his usual Scotch humor, his paper calls for considerable thought, for up to the present time I scarcely think it possible to say just exactly at what point it is most advantageous to drop the reciprocating engine and enter the turbine field.

We do know that from 7 to 15 pounds absolute is what has been claimed the economical point by turbine experts, but even Mr. Parsons says we may go higher than 15 pounds absolute. In modern steam engineering practice we have two separate and distinct conditions to meet, namely, one of pressure, "which is best cared for by the piston engine," and the other of volume, which is best cared for by the turbine. It has been clearly shown in practice that we can get about the same power from atmospheric pressure down to 28 inches of vacuum as we can from 200 pounds pressure down to atmosphere.

It has also been shown that by taking the Corliss compound engine and supplying the waste steam to the turbine, we can get 33 per cent. more power, from the same coal pile, and that by rearranging the valve gear of the reciprocating engine we can get as much as 50 per cent. increase in power from the same coal pile. (See Interborough test.) These are indisputable facts and we can not afford to lose sight of them. Of course, we all welcomed the turbine with its ideal motion, and I believe we have all come to the conclusion that it has come to stay. We must not, however, lose sight of the fact that economy plays a most important part in our engineering work of to-day, and therefore any scheme that is proposed for the propulsion of ships must be finally settled on its all around economy, viz., wear and tear, upkeep and fuel consumption.

Mr. Dickie suggests several very good features in his paper, the principal one

being, the best combined Reciprocating Engine and Turbine arrangement, but as he says, if he thought the members would agree with him, he would never have written the paper.

Now, I think we all agree that one of the great troubles that we have with the present turbines and reciprocating engines applied to marine work, is the fact that we are dealing with a poor valve gear. In the stationary practice we have the Corliss valve gear with its separate exhaust, and undoubtedly that accounts for much of the economy we fail to get in marine work.

In going over this subject, I took great pleasure a few days ago in renewing my acquaintance with what I consider the best reciprocating engine in the world to-day, and that is, the engine presented by Prof. J. Stumpf, of the Technical High School, Charlottenburg. Prof. Stumpf, as some of you will probably recall, published an account in the London "Engineering" of June 10, 1910, of what he termed a uni-directional-flow engine. It has several advantages which are suggested by Mr. Dickie's paper, inasmuch as you are able to pass at least four times more volume of exhaust than is possible with any other type of engine that I know of, and for those who are not familiar with the subject, I had a large print made showing Prof. Stumpf's cylinder, I would like to have this blue print pinned up on the blackboard, if I may, Mr. President. (The blue print was tacked on the blackboard.)

I would like to call attention to some of the features of Prof. Stumpf's uni-directional-flow engine. Mr. Anderson said that 12 per cent. was about as good as they obtained in the combined system of screw propulsion. Well, 12 per cent. is ridiculously low. If we can get results at the Interborough Railway Station amounting to 50 per cent. increase of power on the same coal consumption, I do not see why we can not get at least 30 per cent. out of a proper combination on a steamship and, with this combination, which I propose as the best (though like Mr. Dickie's it will have to be proven), I think we may expect fully 50 per cent. economy by a proper combined arrangement.

Mr. Lovekin here read extracts from Professor Stumpf's article in London "Engineering" of June 10, 1910, and said:

Now, the point is this, that assuming all of these features known to exist in this particular type of engine, and being a single expansion engine it makes a splendid unit for the combined scheme, doing away with all the disadvantages which Mr. Dickie has pointed out in his article, being an engine in which expansion can take place in one cylinder it seems to be as near the ideal for a high pressure unit as the present turbine is for a low-pressure unit.

Prof. C. H. Peabody:—May I inquire whether this has anything to do with turbines?

Mr. Lovekin:—Yes, it is a combined system.

Mr. Charles P. Wetherbee, *Member:*—There is one feature in connection with the low-pressure turbine, in combination with the reciprocating engine, that I do not think has been brought out in connection with Mr. Anderson's paper. The steam is at such low-pressure in the steam belt of the low-pressure turbine that, the ordinary type of axial dummies or what you might call contact dummies that is used in Parsons turbine need not be employed, and the radial type of dummies, such as is usually used, with the astern cylinders, can be employed with a very small loss of economy.

Furthermore, the tip clearance of the blades, which has been criticised in some cases in the past, can be greatly increased without any serious loss of economy. The radial dummy feature permits the use of a turbine that does not require any accurate means of obtaining the fore and aft position of the rotor, with reference to the cylinder, and does not require any accurate thrust adjustment, for the reason that this dummy will permit great longitudinal motion of the rotor without any damage.

These two things together overcome in this low-pressure turbine the criticisms that have been made of fine clearances in the Parsons turbine, and furthermore, a thrust-block can be used on this turbine that does not have the thrust on one-half of the collars only. The top and bottom halves can both be used with a thrust-block of the ordinary type, because the amount of float allowed in the thrust-block used with reciprocating engines is not sufficient to permit the rotor to touch any part of the cylinder. These are of very great advantage.

Mr. W. L. R. Emmet, *Member:*—In connection with the subject of the use of reciprocating engines with turbines, I want to call attention to a method which I proposed in connection with the battleships Wyoming and Arkansas, which I think can be easily proved to be far better than the methods which are shown in Mr. Anderson's paper and can be put in practice on many ships. I do not advocate this method which I then advocated, because I have since proposed a better one; but if people must use reciprocating engines with turbines, I think that the proper way to do it is to exhaust the reciprocating engine into a high-speed turbine. Let that high-speed turbine drive a generator and put the power back on to the reciprocating engine shaft with a motor. There would be absolutely nothing problematical or peculiar about this. The turbine machinery has to do no reversing, it has to perform no functions that are not generally performed by turbines and generators and motors everywhere, and it conduces to a very much better efficiency of the turbine, because the turbine can run at the speed which is most desirable. It receives the steam from the reciprocating engine at any desired pressure, any proportion of the total work of the steam can be put upon the shafts by this method, and the system is perfectly flexible.

For some unaccountable reason the shipbuilders of the world and the naval architects of the world seem to have decided to ignore electric propulsion of vessels. Being used to seeing new things commercially adopted when their merits could be demonstrated promptly, this is a strange condition to me.

I want to say in this connection, while it is not a direct discussion of the paper, that the same advantage which applies to this combination of reciprocating engine and turbine applies in many cases to the use of the turbine alone with electric transmission, and I want to call attention to just one specific case which I have recently investigated. Two years ago I presented a paper to this Society on the subject of electric propulsion, and I showed certain advantages which I believed to apply to that form of propulsion. I have worked out many cases since then, and I want to stand here and tell everybody who will listen that two years of careful thought and study have not changed my opinion one iota, but have strengthened it, and I want to tell of one specific case which I recently investigated, of a ship similar to a large Trans-Atlantic liner, a ship something like the Celtic, about 17,500 horse-power and a speed of about 17.5 knots. In that ship I can put in an electric equipment, using a generating unit which has actually been built and tested, and is completely understood. I can put in an electric propelling equipment which will weigh 500 tons less than the engines of the ship. Its water rate will be 2.5 pounds better than the water rates which Mr. Anderson has stated, and which the builders of the ship in question vouch for. If this ship was equipped and run on a regular Trans-Atlantic trade, the saving in coal, incident to her operation, would amount to about $20,000 a year. The saving in weight of coal carried would amount to something like 400 tons, so that her cargo capacity would be increased by 900 tons, and you would have a very much simpler equipment, requiring the employment of a much less number of men, and would have nothing on that ship which could, in any sense, be considered experimental. You would have motors of a very ordinary type, large, extremely large motors, but the electrical features in them would be those which are well understood and in common use. The turbine generating unit would be just such a generating unit as is now operating in many parts of the world.

Furthermore, within very recent times better water rates have been produced in such high-speed generating units, so that, whereas the figures upon which this comparison is based, contemplate 11.5 pounds per shaft horse-power in this ship, with some of the very best turbine generating units which have been recently tested that result would come down to 10.5 pounds per shaft horse-power and a saving in weight of coal carried would be proportionately increased. And no engineer has yet come forward who could show any cause why these things are not true.

I think it is the duty of the navies of the world and the people who are responsible for the designing of the marine equipment to either use these methods or disprove their utility.

THE PRESIDENT:—Is there any further discussion on this subject?

PROF. H. C. SADLER, *Member of Council:*—I would like to ask the last speaker if he can give us any figures as to the comparative costs?

MR. EMMET:—In the case that I mentioned we made a proposition on the equipment of this vessel—it was made without knowledge as to whether it was to be seriously considered or not—but we made it in good faith, exactly as we would if we had to contract for it. Our price for this 17,500 horse-power equipment was $220,000, and from the best information I can collect concerning the cost of reciprocating engines in such a ship, I think it is at least $50,000 less than they could be built for.

MR. WETHERBEE:—I ask whether the price named was a special price, in view of introducing the machinery, or actually based on the cost?

MR. EMMET:—That price was at a rate of profit considerably better than the average profit of the General Electric Company on the turbines manufactured for the past three years.

MR. WILLIAM T. DONNELLY, *Member:*—There are reasons, business and otherwise, for the installation or non-installation of turbines, and I should like to add just a little information to what Mr. Emmet has said. Though my business is somewhat different, I have given a great deal of study to the application of electricity to marine work, and I believe we will all see the ultimate triumph of electricity as a motive power at sea.

Sometime ago I designed a floating dry-dock and was negotiating with an engineer in Paris, who thought he could put his hand on an order for one and I took the matter up with the steel people here. They said, "Yes, we know the cost abroad and think we can handle the business, but we have put in figures to handle similar business and failed to get it when the price was right. Will you ask your engineering friend if the business will be placed strictly on the price?" The preliminary negotiations for the transaction were completed on that basis and the engineer in Paris frankly admitted that he had obtained information that it would not be placed strictly according to the price. We know that here and in foreign countries there are large business aggregations that are manufacturing and constructing many of these appliances and they push them on the business end sometimes to the exclusion of engineering considerations.

I think that the building of the ships referred to and the introduction of steam turbines for propulsion in contradistinction to electric motors was strictly a business enterprise, and as such was perfectly legitimate. On the other hand, it is entirely proper for engineers in a society such as our own, to criticize such business methods, particularly when they are brought forcibly before us in engineering papers which would seek to make them strictly engineering matters. As to the ultimate outcome, I have not the slightest doubt. The steam turbine as a generator of power will probably never be excelled, and it is equally or more positively a fact that, as a means of utilizing power, the electric motor will come to its own in marine work as it has for nearly all other purposes.

SIR WILLIAM HENRY WHITE, *Honorary Member:*—I do not propose to say anything on the subject of the electric drive in steamships, but the meeting perhaps will permit me to say a word or two from the standpoint of the naval architect. I do not think naval architects are quite so apt to run in grooves and not consider new propositions, as Mr. Emmet would suggest.

He must be aware, if he has followed recent events in England, that we have had long discussions at the Institution of Naval Architects, at the Institution of Civil Engineers and at the recent meetings of the British Assocition on this very subject. In the last mentioned discussion which took place at Portsmouth, in September, we had the advantage of a description by Mr. Mavor, of Glasgow, an electrical engineer of repute, of the equipment and performance of an electrically driven launch embodying the system of electric drive which Mr. Mavor advocates. I need not recapitulate the grounds on which up to date in Great Britain the electric drive has not been favored; they are to be found in published reports of discussions to which I have referred. In my judgment, and I am by no means a conservative person as my record shows, the point has not yet been reached at which it would be desirable to experiment on a large scale in that direction and in saying that, I have the greatest respect for the opinions expressed by electrical engineers.

In regard to Mr. Donnelly's remarks, I desire to say that while it is extremely difficult to separate business considerations and scientific or professional considerations, Mr. Anderson's paper ought not to be regarded as a business advertisement. There is moreover a sense in which the statistical statements in Mr. Anderson's paper are of very great interest to Naval Architects and Marine Engineers. The practical application of the marine steam engine turbine began in 1897, when the Turbinia made her appearance at the Naval Review at Spithead. In the interval since 1897 (fourteen years) there has been a revolution—no other word can express the change—in the system of marine propulsion. No similar or equal change can be mentioned as having occurred in that short period of time. From that point of view I think the facts will bear recording even in a paper to be read before this or any other technical society. If anything in the nature of advertisement were intended by such a record, I should entirely endorse the view that it would be undesirable, but I do not think that any such intention existed, and certain facts enumerated and recited in the paper are only repetitions of what has been published previously.

I desire to add a word about Mr. Dickie's paper. Mr. Dickie has no doubt worked out his scheme absolutely independently, and the description of it given on the bottom of page 190, reminds me of what was done in England in connection with cargo steamers several years ago by Sir Charles Parsons. It was identical with the proposal made by Mr. Dickie. In Sir Charles Parsons' scheme the central single shaft of the ordinary cargo steamer and large propeller, were retained; and in association therewith smaller propellers were proposed, one on each side, to be driven by low-pressure turbines. The design was worked out in detail, and but for special circumstances to which reference need not be made it would have been applied to

cargo steamers trading out of the port of Liverpool. Since that date, of course, the gearing system has been tested in the Vespasian over a long period, and on voyages aggregating from 30,000 to 40,000 miles, so that the earlier proposal has been set aside.

The "combined" system has been applied, however, in many vessels of the intermediate class. Having personally had much to do with that arrangement I cannot speak of it impartially, but I wish to say that if such enormous economies as those described by a previous speaker, who attached his blue print to the blackboard, could possibly be obtained, by all means let the scheme be worked out and put forward in the form of a tangible proposition. I can guarantee that great British shipowners who are always endeavoring to secure even a fraction of one per cent. economy in the working of tramp steamers will jump at the thing if it is practicable. Behind the assertion of such large possible economy, if it were examined in detail, I think there would be found assumptions of the use of high superheat in the steam, or some other details of which little may have been said, but in regard to which serious differences of opinion prevail. That statement applies to many of these suggestions of possible economies in water or steam consumption. Right or wrong, the feeling of the British Admiralty up to date after gaining a very large experience with turbines, and after considerable but not altogether satisfactory experience in the use of superheated steam on shipboard—was recorded not long ago by the Engineer-in-Chief, Admiral Oram, and was not favorable to the use of high superheat for marine engines. It is, of course, a distinct question, whether or not superheat ought to be used, and I only refer to it, because many statements of possible economies and improvements upon what has been obtained ignore the fact that one important element in economy is intended to be the use of a high superheat.

Mr. Anderson's paper appears to be a compilation of information which was previously scattered. No doubt it illustrates the important fact, that Sir Charles Parsons—whose name will always be associated as the leading spirit in this revolution in steam machinery, although the claims to consideration of other workers in that field are fully admitted—has from the first realized and acted upon principle that no single arrangement of machinery can admit of universal application or will give the highest efficiency in all cases. He has been ready from the first and stands ready to-day, to consider every problem on its merits. In the varied solutions which are mainly due to him, he has given proof of his catholicity of choice and his openness of mind, and these are qualities which my large experience with inventors makes me believe to be exceptional.

Mr. Emmet:—May I say one word more?

The President:—Please be as brief as possible, Mr. Emmet.

Mr. Emmet:—There are one or two points I failed to mention. One is that this installation I spoke of as applying to a 17,500 horse-power ship, could be put into any existing ship of that class—you could lift her engines out and put them on

the wharf and put that equipment in—and it would be guaranteed to do these things which I have stated, and if it did not do them, the equipment could be lifted out again and the old engines put back in their place, and no harm done. The same applies to the battleship proposition. This same applies to the Collier Jupiter, which we are equipping. If this equipment does not do all things we promised, it will be replaced with reciprocating engines.

No superheat is considered in connection with any of these propositions. They are on the saturated steam basis, and the same boiler pressure which is needed for reciprocating engines.

Sir William Henry White:—Mr. Emmet, will you kindly say if your price assumed that the propeller shaft and propeller remained?

Mr. Emmet:—That is the price for replacing the engine alone, nothing but the engine.

Mr. Lovekin:—In reply to the remarks of Sir William Henry White on the question of superheat—I said nothing about superheat—in fact I was not through with my remarks when interrupted, I can say however that with steam having 92 per cent. moisture, I have figured out the consumption of a Stumpf unit in combination with a low pressure turbine and find that a water rate of about 10.5 pounds can be guaranteed. I base that largely on my experience with the battleship Michigan engines, which were designed previous to the Delaware, and which are somewhat similar, the Delaware has a water rate of 12.5. This is indisputable. Now if the Delaware has 12.5, as against 16 to 20 pounds which all the previous battleships' engines have had, and we attach a low pressure turbine to this engine, we should also get a water rate of 10.5, with the use of superheat.

Mr. Dickie (Communicated):—Being unable to be present and take part in the discussion on my paper, I find it necessary to communicate what I would have liked to have said. In regard to Mr. Monteagle's criticism of my proposal to use a four cylinder compound engine on the central shaft instead of a three cylinder triple expansion engine, the question of a particular type of reciprocating engine is really no part of the discussion as to the best arrangement for combined reciprocating and turbine engines on steamships, but only my own opinion of the simplest form of reciprocating engine to use in the arrangement I propose. I did not propose any increase in the initial pressure of 195 pounds to 205 pounds absolute, and at that pressure exhausting at 30 pounds absolute the type of engine I indicated would give good economical results.

Mr. Monteagle's second criticism on the omission of the backing turbine, which he believes should be prohibited. In the arrangement I proposed there was about 60 per cent. of the total power available for backing and that is more than is usually provided in turbine ships. What Mr. Monteagle would prohibit would apply to all single screw ships and would put out of commission at least 75 per cent. of all the steamships afloat.

Mr. Monteagle's third criticism in regard to the valve gear is merely a matter of opinion. The valves would be all of the piston type, would not be heavy and the valve gear, of which there would only be two sets, if made as heavy as the weight of the four sets, would, in my opinion, be better insured against possible breakdown.

Mr. Lovekin's address was not in any sense a discussion of my paper. His suggestion that Professor Stumpf's unidirectional flow engine might take the place of the reciprocating engine I suggested is the only connection that his remarks have with my paper. I do not think Professor Stumpf would like to have his type of engine helped out by a turbine as his claim is that the engine he is developing is in itself the old reciprocating engine and the turbine combined—in fact better than any combination of the two. I think Mr. Lovekin would find some difficulty in getting the steam out of the unidirectional flow cylinder into the receiver of the turbines, in fact it must have a pretty big stepdown to get out at all and if it doesn't get out quickly the engine stops.

In regard to what Sir W. H. White said in his reference to my paper, I am pleased that he brought out what had been done several years ago by Sir Charles Parsons. I did not claim any originality for what I presented in my paper, in fact I stated in closing that all I had brought before the Society had of course been considered by the able engineers who have designed the important installations of combined reciprocating and turbine engines, although I do not remember the particular work referred to by Sir W. H. White. I am sure he will understand that out on the Pacific Coast we are not in so close touch with everything that goes on in the great shipbuilding centers as we should be and consequently sometimes do work that we are foolish enough to consider original when it has been done before elsewhere.

I am disappointed that the economical point in the expansion curve at which to turn over the steam from the reciprocating engine to the turbine was not discussed.

The President:—I congratulate the Society on having had presented to it papers which have produced such interesting discussion, but time is pressing and we must, with the thanks of the Society to the authors of these papers, proceed to further business. The council must have a meeting to consider further applications for membership. This meeting will adjourn until 2.30 o'clock. The Council will kindly assemble as quickly at possilbe as the front of the room.

The meeting then took a recess.

Afternoon Session.

President Taylor called the meeting together for the afternoon session at 2.30 o'clock.

The President:—The Council held a meeting during the recess and passed upon a number of applications for membership in the Society, and I will ask the Secretary to read that list.

The Secretary:—The following names were favorably passed upon for the various grades for election as members:

ELECTIONS TO MEMBERSHIP.

For Members (5).

E. A. Burnside, Manager, Campbell's Creek Coal Co., Point Pleasant, W. Va.

A. A. Kennedy, Port Engineer, Mallory S. S. Co., 457 75th Street, Brooklyn, N. Y.

A. S. Hebble, Superintending Engineer, Pier 49, N. R., New York, N. Y.

W. F. Lee, Chief Engineer, C. W. Hunt C., West New Brighton, N. Y.

W. A. White, President and Treasurer, Washington Engine Works, 601 Washington Street, New York, N. Y.

J. S. Allen, Metropolitan Dredging Co., 115 Broadway, N. Y.

For Associates (7).

A. W. Frank, Assistant Naval Constructor, U. S. N., Navy Yard, Boston, Mass.

P. G. Lanman, Assistant Naval Constructor, U. S. N., Navy Yard, Boston, Mass.

H. O. Nickerson, General Manager, New England Navigation Co., Pier 19, N. R., New York, N. Y.

G. A. White, Assistant General Manager, Hudson River Line, Desbrosses Street Pier, New York, N. Y.

E. M. Bull, Vice-President, A. H. Bull S. S. Co., 10 Bridge Street, New York.

A. A. Cameron, 940 Fourth Avenue, East, Owen Sound, Ont.

From Junior to Member (4).

A. V. Curtis, Draftsman, Navy Yard, Washington, D. C.

L. M. Thompson, Draftsman, Bureau of Lighthouses, Washington, D. C.

D. Bailey, Draftsman, Navy Yard, New York, N. Y.

J. Friebele, of J. W. Ferguson Co., 152 Market Street, Paterson, N. J.

For Juniors (3).

F. Carlsen, Student, Webb's Academy, New York, N. Y.
G. A. Colley, Student, Webb's Academy, New York, N. Y.
G. A. Newton, Draftsman, Whittelsey, 11 Broadway, New York, N. Y.

THE PRESIDENT:—You have heard this list read, gentlemen, which has been passed upon by the Council. What is your pleasure. A motion that these gentlemen be declared elected will be received, unless you want a ballot.

MR. W. T. DONNELLY, *Member:*—I move that the applicants who have been passed upon favorably by the Council be elected to membership.

THE PRESIDENT:—Gentlemen, it has been moved and seconded that the gentlemen named in the list read by the Secretary be declared members of this Association to the grades named. Those in favor of passing this motion say aye; contrary minded, no. The motion is carried, and the gentlemen are declared members in their respective classes.

If any of you have not prepared yourselves for the banquet this evening, I trust you will do so at the earliest possible moment, to give the Secretary-Treasurer a chance to see that you are properly seated.

The next paper in order is entitled, "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Messrs. Frank E. Kirby and William T. Donnelly, Members.

Mr. Donnelly presented the paper.

THE MARINE TERMINAL OF THE GRAND TRUNK PACIFIC RAILWAY, PRINCE RUPERT, BRITISH COLUMBIA.

By Frank E. Kirby, Esq., and William T. Donnelly, Esq., Members.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

When, in 1910, the authors of this paper were retained to visit the Pacific Coast for the purpose of studying the shipping and marine repair facilities and to visit Prince Rupert, the western terminus of the Grand Trunk Pacific Railway, they were at a loss how to proceed, for not only was Prince Rupert beyond their geographical knowledge, but it also failed to appear upon any available map or chart. However, with an abiding faith in the Grand Trunk Pacific, they undertook the commission.

Proceeding to the Pacific Coast over the Northern Pacific, they visited Portland, Seattle, Tacoma and Bremerton in the United States, and Victoria, Vancouver and New Westminster, British Columbia, finally proceeding from Vancouver on the Canadian Pacific Steamer northward through the inland passage, and after three days steaming through the narrow waterways which were literally the submerged valleys of the Coast Range, they arrived on the evening of the third day in the Harbor of Prince Rupert and were, for the first time, fully convinced that such a location actually existed.

Those who are especially interested and desire to extend their geographical knowledge, are referred to the most recently published charts of the Northern Pacific and Alaskan coasts, on which Dixon's Entrance, North of Graham Island between 54 and 55 degrees north latitude, can be readily located. To the east of Dixon's Entrance, Brown Pass leads to Chatham Sound and across this to the east, between Digby and Kaien Islands, is found Prince Rupert Harbor. So hidden away and unprepossessing is the entrance that until 1906 it was supposed to be unnavigable. Actual surveys show it to be one of the most easily entered and satisfactory harbors on the Pacific Coast. The entrance, which is from the south, is about three-eighths of a mile wide. It is entirely unobstructed with a depth of water nowhere less than twenty fathoms. The entrance may be said to extend northward for three miles, when the harbor is reached, extending northeast for four miles, with an unobstructed width of from one and one-half to three-quarters of a mile.

The city of Prince Rupert is located on Kaien Island which forms the

right of the entrance and the southeast shore of Prince Rupert Harbor. The city proper is laid out over an area three and one-half miles in length by one mile in breadth, on the shore of the Island, with a background rising to an elevation of from 1,600 to 2,000 feet, the general characteristics reminding one very forcibly of the city of Montreal with Mount Royal behind it.

The Grand Trunk Pacific Railway will reach the Coast by the Skeena River valley about 15 miles to the south, and crossing to Kaien Island at its southern end, will closely follow the shore to and along the water front of Prince Rupert.

The general character of the shore of Prince Rupert is bold and rocky, falling off very rapidly to a depth of approximately 20 fathoms. A careful examination of the entire length of the harbor front of Kaien Island determined Hays Cove as the only practical place for such a development as was contemplated; that is, a floating dry-dock of 20,000 tons lifting capacity, so designed as to be capable of operating in sections as a number of smaller docks, an adequate shore plant comprising electric power generating plant with air compressors, machine shop, boiler and blacksmith shop and covered construction shed under which the pontoons of the floating dry-dock could be built.

The dock is to be of such a design and construction as to be almost entirely built upon the site. To accomplish this, the general plan provides for the practical completion and equipment of the shore plant before the dry-dock is commenced.

One of the controlling features in the general plan of this development was the fact that the city of Prince Rupert will be 600 miles from the nearest base of supply or point where any considerable assistance, mechanical or otherwise, can be obtained. It was therefore determined at the outset that the mechanical equipment, large tools, etc., must be of the very best and most complete. Also, that on account of the high price of labor on the Pacific Coast, ample provision for the use of power in every way possible should be made. This has resulted in the design of an electric power generating station with ample capacity for all present needs and with a large possibility of extension.

As the plans were laid out in such a manner as to make the development progressive, constructing those parts first which could, when completed, be used in the construction of the remainder, this outline will be followed in the description.

By referring to Plate 107, there will be found a general plan of the plant, giving location of the dry-dock, piers and buildings.

PIER AND PLATFORM WORK.

The first work to be undertaken will be the pier, marked "Pier No. 1" on the general plan. This will be 420 feet in length and 60 feet in width, the piling being on 10 x 5-foot centers. The pier will require about 600 piles.

At the same time, there will be built the platform at the shore end of this pier 80 feet wide by 930 feet long, having an area of 74,400 square feet, and will require about 1,600 piles on 5 x 10-foot centers.

At the western end of this platform there will be an extension off shore 350 feet long by about 100 feet wide, and at right angles to this an extension 560 feet long by 80 feet wide for the attachment of the floating dry-dock. It will be noticed that a double line of diagonal bracing is used in the pile work. This is on account of the excessive rise and fall of tide at Prince Rupert, which for spring tide is 25 feet. The tops of the piles are thoroughly secured by double 6 x 12-inch clamps and connected by 12 x 12-inch caps. The decking is to be of 4 x 12-inch planking. Piles are to be creosoted. The total area of the platform and pier work will be 181,400 square feet. The completion of this work, it is expected, will provide ample space for the landing and handling of materials for the rest of the plant.

LAUNCHING PLATFORM.

In front of the main platform, east of the pier, there will be built a launching platform for side launching. This will be 80 feet wide by 440 feet long and will be carried on 16-inch piles on 5 x 10-foot centers, braced and reinforced by heavy piling along the edge over which the launching will take place. The general arrangement and bracing of this piling can be seen by referring to Plate 108, showing the platform in connection with the building shed. It will be noticed that the outer half of the building platform has a slope of one and three-fourth inches to the foot, which is approximately the launching grade for side launching.

POWER-HOUSE.

The general location of the power-house will be seen by referring to Plate 107. The interior arrangement and equipment can be seen by reference to Plate 109. Electric power is to be furnished for operating the pumping machinery of the floating dry-dock, for compressing air and to operate machinery in the various shops; also, for furnishing electric lighting for the plant.

The building is to contain both boilers and power plant under one roof with fireproof dividing walls, and is to be 104 feet wide by 148 feet long, having a covered area of 15,392 square feet. The building will be of modern steel-frame construction, the walls and roof to be of reinforced concrete.

There will be installed six 400 horse-power water tube boilers, supplied with automatic stokers, chain-grate type, such as are known to give good satisfaction with Pacific Coast coals. Provision is made for adding two extra boilers. There is also a provision for the installation of an economizer, in case it is found that the load factor warrants the expense. Draught will be obtained by a steel or concrete chimney 175 feet high and 11 feet in diameter. An overhead trolley is provided for handling coal from storage to hoppers above the stokers and also for handling ashes.

COAL HANDLING AND STORAGE.

Provision is made for receiving coal both by water and rail. Coal by water will be received at the outer end of the pier for the unloading of which there is provided a standard grab-bucket installation, so arranged as to load cars beneath the hoppers, the cars to be handled by small yard locomotives to the coal pocket of 1,000 tons capacity, located adjacent to the boiler house. Coal received by rail will be delivered direct from the cars of the Grand Trunk Pacific Railway, which pass at the rear of the property, to the coal pocket approached by an incline.

MAIN ENGINES.

There will be two main engines of 900 horse-power each and while vertical reciprocating compound engines are shown and specified, using steam at 175 pounds pressure and 258 revolutions per minute, turbine engines will be considered as an alternative.

CONDENSERS.

Jet condensers are shown, but alternate figures will be taken for service condensers. The type to be used will depend upon local conditions as to the cost of water at the time of installation. Condensing water will be obtained through the rock cutting and shaft sunk within the power-house, the circulating water being handled by a vertical centrifugal pump operated by an electric motor.

GENERATORS.

Electric generators are to have a capacity of 600 kilowatts, 3-phase, 25-cycle, 550-volt alternating current. For these generators there will be provided two steam-driven exciters, one of 50 kilowatts and one of 25 kilowatts capacity. These machines are to be direct current, 220 volts. There is also to be a motor-driven exciter of 25 kilowatts capacity, the motor for this machine to be a 35 horse-power, 3-phase, 25-cycle, 550-volt alternating-current squirrel-cage-type motor.

CRANES.

There will be provided for the erection of this machinery in the power plant, a 15-ton overhead traveling crane. This will be operated by electricity and the current supplied will be from one of the steam-driven exciter sets.

AIR COMPRESSOR.

For furnishing compressed air to the shops of the plant, there will be provided a compound Corliss air compressor having a displacement of 1,580 cubic feet of free air per minute when operating at 150 revolutions. This compressor is to be designed for a steam pressure of 175 pounds per square inch and for an air pressure of 100 pounds. The distribution of the air will be by means of underground piping through the yard.

SWITCHBOARD AND DISTRIBUTION SYSTEM.

The entire system of light and power throughout the plant is to be controlled from the switchboard located on the main floor of the power-house. The arrangement of the wiring diagram for the entire distribution is shown in Plate 110. The switchboard is to consist of 15 panels. The construction throughout is to be most substantial and thorough, fully meeting the best standards of central station distribution.

CUT AND FILL AND FOUNDATIONS.

By referring to Plate 107, showing the natural conditions of the site, it will be seen that the ground is very difficult, all the property either having to be cut down or raised to grade by fill. The location of the power-house was determined by the condition of the ground, which, at this location, is of rock which will have to be reduced to the grade required. The cut and

fill work is intended to go forward at the same time as the pier work, and the power plant will be commenced as soon as the site can be leveled.

The rock cut for the power-house and yard grading will amount to 18,000 cubic yards, the rock fill for retaining walls, 57,000 cubic yards, and the earth fill for grading, 73,000 cubic yards. The dredging between the pier and dry-dock bulkhead will amount to 100,000 cubic yards to obtain a depth of water of 20 feet at low tide.

BOILER AND BLACKSMITH SHOP.

By referring to Plate 111, there will be seen the design and construction drawings of the combined boiler and blacksmith shop. This is to be 76 feet wide by 150 feet long, the central part to be 33 feet wide, provided with a 15-ton traveling crane. The design is of the usual steel-frame shop construction and will, in this instance, be covered with wood. The flooring will be of concrete with heavy foundations for the large tools.

The tool equipment will be very complete, comprising heavy punch and shears, rolls, plate planer, flanging clamps, etc., heavy steam-hammer and a full equipment of blacksmiths' tools.

MACHINE SHOP.

The building for the machine shop will be constructed from the same set of plans as the boiler and blacksmith shop. The flooring will be of concrete with special foundations for large tools. Ample provision is made for thorough lighting and the building will be steam heated throughout.

A very complete equipment of machine tools will be provided, comprising all machinery necessary to handle the heaviest crank and other shafting of large steamers; also, boring, drilling and turning machinery for repairing all the secondary machine equipment of steamships. Large tools will be driven by individual motors, the smaller tools being arranged for group driving. A 15-ton overhead traveling crane will be provided for both boiler and machine shops.

The building will be supplied with compressed air and a special room will be fitted up for the repair and care of air tools.

By referring to Plate 107, it will be seen that the location of the machine shop is such that ready access may be obtained from the dry-dock and water front, and it will be noticed that provision is made for entering the boiler and machine shops with railroad cars. Provision is also made for the extension of these shops as the business develops.

BUILDING SHED AND WOODWORKING SHOP.

On account of the excessive rainfall in Prince Rupert, it will be necessary to do the work of building the pontoons for the floating dry-dock under cover.

In laying out the general plan for the property and in view of its future development, the possibility of shipbuilding was carefully considered, and while there is no immediate prospect for the building of steel vessels so far from the base of material, it was thought advisable, in preparing for the building of the pontoons under cover, to make the construction of a permanent nature, suitable for shipbuilding, to be used in the immediate future for wooden shipbuilding and later on for steel shipbuilding. To accomplish this the building shown in Plate 108 has been developed. This building is located over the launching platform and over part of the general platform extending eastward from Pier No. 1, with foundations carried down to rock.

It will be seen from the general plan, Plate 107, that the property is laid out for side launching, this being the only practical development that was possible under existing natural conditions. The building about to be described is the result of these conditions.

While side launching is unusual in Europe and generally in America it is practically universal on the Great Lakes, and the general design of this structure is the result of experience there.

The shipbuilding portion of the structure is designed to have a covered width of 86 feet by 300 feet long, with a clear height under cranes of 50 feet and under girders of 56 feet. The shop section of this building is to have a width of 80 feet and a length of 300 feet. The ground floor will be used for machinery and the upper floor will be used as a laying-out floor.

The equipment of woodworking machinery will be most complete, comprising large re-saw band saw, timber sizer, rip and crosscut saws and other woodworking and finishing machinery.

ADMINISTRATION BUILDING.

There will be an office and administration building 40 feet wide by 100 feet long, constructed of wood two and one-half stories high. This will be fitted up with draughting room, accounting and bookkeeping department and private offices. The exact location of this building has not been determined, as this will depend largely upon the opening and grading of streets approaching the property.

20,000-TON PONTOON FLOATING DRY-DOCK.

Referring to Plate 112, there will be seen the general design drawing of a 20,000-ton pontoon floating dry-dock, description of which has been reserved until the last from the fact that, as previously stated, it was to be almost entirely constructed at and by the plant of which it is to be the principal feature.

This dock is to have an over-all length on keel blocks of 604 feet 4 inches, a clear width of 100 feet and a width over-all of 130 feet. The lifting power is the aggregate of twelve pontoons of timber construction, each 130 feet long corresponding to the width of the dock, 44 feet wide in a direction corresponding to the length of the dock and 15 feet deep. These pontoons are to be united by steel side walls or wings 38 feet high, 15 feet wide at the bottom and 10 feet wide at the top, the walls being divided so that the whole structure may be used under ordinary conditions as three separate docks, one of six pontoons, with an over-all length of 269 feet, and two of three pontoons each, with an over-all length of 164 feet each. The largest commercial ship upon the Pacific Coast at the present time is the Minnesota, the outline of which is shown on the dock. This vessel would have a dead weight in ordinary unloaded condition of approximately 18,000 tons.

The machinery for pumping the dock will consist of centrifugal pumps operated by electric motors, the capacity of the equipment being sufficient to pump the entire lifting power of the dock in less than two hours. A detailed description of the pumping machinery will be given later.

The structure as a whole is secured to the shore by the engagement of clamps on the dock with a vertical truss secured to the pile platform or pier in such a way that it is free to rise and fall with the tide, and when being raised or lowered with a ship. The location of these attachments is such that when it is desired to use the dock in three separate sections, the bow section may be detached and moved around the corner of the pier work located as shown on the general plan alongside the platform, and secured in the same manner as provided for in its original position. To make the other two sections available as separate docks, it is only necessary to detach the middle section, comprising six pontoons, from the pier work and advance it the length of the detached section, when the sliding clamps upon the wings will coincide with those used for the previous section when the dock was operated as a whole. This will allow ample space between the center and stern sections for the overhang without interference of vessels which may be docked on them.

As the feature of a sectional dock to be used as a whole or separately is somewhat new, it is desired to call attention to the fact that the three largest commercial docks in the United States, namely, the 10,000-ton floating dry-dock of The Tietjen & Lang Dry-Dock Co., built in 1900, the 12,000-ton dock of the Morse Dry-Dock Co., built in 1902 (both in New York Harbor), and the 10,000-ton dock of the Port of Portland, Portland, Oregon, are sectional docks in five sections each. All of these docks are of timber construction and are giving excellent service.

PONTOONS.

As previously stated, the pontoons for this dock are to be twelve in number, constructed entirely of timber. By referring to Plate 113, there will be seen the design and construction plan of these pontoons. They are to be 130 feet by 44 feet by 15 feet deep, with a crown of 3 inches at the center, and will have 15 trusses spaced on 3-foot centers. There will be a center water-tight bulkhead 12 inches thick and above this bulkhead the center will be reinforced for carrying keel blocks. There will be three partial bulkheads on each side to stiffen the pontoons. All diagonal braces are heavily reinforced with anchor stocks. The arch brace is made up of planking through-bolted with screw bolts and is intended to take the reverse stresses when the dock is floating light. This is a considerable amount when it is considered that the wings are superimposed weights carried at the extreme ends of the trusses, supported by an evenly distributed pressure over the entire bottom. Six by 12-inch deck beams are worked across the upper and lower truss members, carrying the 5-inch deck and bottom planking parallel to, and reinforcing the truss members for the maximum stress. This construction also makes it possible to get in double vertical tie rods alongside of bulkheads in such a manner that they may be replaced at any time. The whole structure is made water-tight by caulking with white pine wedges.

To protect the exterior from toredo and other marine worms, it is first thoroughly graved with tar poisoned with arsenic, then sheathed with two layers of hair felt, each thoroughly saturated with tar and arsenic, and then with creosoted lumber, also treated with arsenic and thoroughly secured with galvanized nails. This treatment, together with the facility for inspection afforded by the possibility of detaching and docking any pontoon, has been found to give satisfactory protection.

Each pontoon will require approximately 330,000 board feet of lumber or a total, including outrigger or prow on the end pontoons, of 4,000,000

board feet. The entire bill of lumber will be of selected grade of Oregon pine or Douglas fir.

As previously stated, it is the intention to have these pontoons built upon the launching platform under the building shed, using the tools and equipment provided for the plant. Sufficient room has been allowed to build three pontoons at the same time. As soon as they are launched they will be moved into the basin between the pier and dry-dock platform and temporarily united together in correct relative position by timber clamps, when they will be ready for the erection of the steel wings.

For further information relative to the use of wood for the construction of floating dry-docks, parties interested are referred to a paper on "Floating Dry-Docks in the United States—Relative Value of Wood and Steel for their Construction," appearing in the Proceedings for 1910 of the Society of Naval Architects and Marine Engineers.

STEEL WINGS.

By referring to Plates 112 and 114, showing the completed structure and the design of the wing trusses and plating, a general idea will be gained of the construction of the wings. They consist of channel and angle frames on 3-foot centers corresponding to the trusses of the pontoons, and a covering of plating varying in thickness from one-half to five-sixteenths inch. The construction is greatly facilitated by reinforcing the plating against water pressure on the outside by horizontal angles. This does away entirely with troublesome intercostal connections and gives the material used very much greater value in the construction as a whole.

By referring to the table of weights it will be seen that there are required about 2,200 tons of steel. Where the wing meets the deck of the pontoon there is a steel shoe secured to the frame of each pontoon and a corresponding shoe riveted to each frame of the wing. These are connected together by a steel link about 15 inches long and pins, the upper one of which is tapered one-half inch to the foot. The driving of this pin wedges the pontoon and wing together. At the point of contact, the bottom of the wing is reinforced by a 12 x $\frac{1}{2}$-inch plate and made water-tight by canvas packing saturated with red lead. On the outer side of the wing the method of securing is similar, except that the shoe on the pontoon is replaced by a cast-steel strap through-bolted to the pontoon.

Provision is made for multiple punching on uniform centers of 3 inches and 6 inches throughout and the intention is to have the material fabricated in Europe or the eastern part of the United States, all frames

assembled and shipped by water to Prince Rupert. The erection of the first section is to be commenced as soon as the first three pontoons are launched, the compressed air machinery of the plant being used for pneumatic riveting.

PUMPING MACHINERY.

The dock will be pumped by twenty-four (24) 12-inch centrifugal pumps, one in each end of each pontoon. By referring to Plates 112 and 114, the general arrangement and detailed construction of these pumps will be seen. The pump suction will take water from the bottom of the pontoon, the suction being protected by a liberal area of screen. Delivery will be directly through the flood-gate used in lowering the dock.

The pumps will operate at approximately 275 revolutions per minute, being driven by a vertical shaft. All the pumps on each side of each section will be driven through gearing and horizontal shafting by one electric motor, as shown in Plate 112. A jaw coupling is provided in the wing at about the level of the top of the pontoon for disconnecting the vertical shaft when the pontoon is removed for self-docking.

There will also be seen in Plate 114 the indicator for determining the level of water in the wings. This consists of a counterweighted float in vertical guides and a vertical rod extending through the deck of the wing. As the water enters the wing the float rises and the height of the rod above the deck will indicate the depth of the water in the wings.

A similar device, not shown, is provided to show the depth of the water in the pontoon. The flood-gates are operated to control the lowering of the dock and also to control the pumping collectively and individually of the different pumps, it being understood that with the pumps running, no water will be delivered if the flood-gates are entirely closed, and that, by a regulation of the gates without altering the speed of the pumps, any degree of control or any distribution of control can be accomplished. In case one side is rising too rapidly, the partial closing of the gate on that side, without disturbing the operation of the machinery, will effect the control, or the gates may be left at the same opening and the machinery stopped.

By this method, a much quicker and more powerful control may be obtained, as not only will the discharge of water from the dock stop, but will immediately commence to enter, thus doubling the power of control which would be obtained by closing the gates.

ELECTRICAL EQUIPMENT.

As previously explained, the group of pumps on each side of each section of the dock will be operated through horizontal and vertical shafting by one electric motor. Thus, for the two smaller sections of three pontoons each there will be required four 100 horse-power motors and for the larger section of six pontoons there will be required two 200 horse-power motors. The motors are to be alternating current, 3-phase, 25-cycle, 550 volt, and will operate at approximately 500 revolutions per minute. They are to have wound rotors and slip rings for variable speed control. The armature shaft is to be extended on both ends and will operate the distribution shafts through reduction gearing at a speed of approximately 275 revolutions per minute.

Referring to Plate 115, there will be seen diagrammatically the location, arrangement and connections of these motors. There will be two motors on each section, one on each wing. The power circuit on the pier is connected to the power circuits on the sections by flexible cables. The power circuits of each section are independent from the main circuit, so that each section receives its power independently, but the control system is to be so arranged that the two motors on any section may be operated from one master panel or the combination of any two sections may be operated from the master panel on either of the two sections, and lastly, when all three sections are used together, all six motors are to be controlled from the master panel on the middle or larger section.

MASTER PANEL.

The master panel is to consist of a panel or drum having suitable contacts or switches for independently starting or stopping any of the motors. The starting or stopping of any one motor or a number of motors will not affect other motors at rest or in operation. The provision is also to be made for operating any or all motors at one-half, three-quarters and full speed.

COMPRESSED-AIR EQUIPMENT.

While steam-driven air compressors are provided in the power plant to furnish compressed air for the shops, it was deemed advisable on account of difficulty due to the extreme rise and fall of tide, to make flexible air connections to the floating dry-dock and to provide an electrically-driven air compressor upon each section.

Referring to Plate 116, there will be seen the general design of the machinery house for the different sections, and on one side of each section there will be provided an electrically driven air compressor having a capacity of 500 cubic feet per minute. The air will be delivered to a receiver in the wing below, and from this to air piping carried along the bottom to each side of the wing, with multiple outlets for the connection of air hose to the pneumatic tools. Provision will also be made for connection between the sections of the dock when they are operating together.

Electric current for operating the air compressors will be taken from the circuits supplying the motors for pumping the dock, and as air will be used only after the dock is pumped up, the capacity of these circuits will be more than ample.

OPERATING EQUIPMENT, BILGE BLOCKS, KEEL BLOCKS, ETC.

Referring to Plate 112, there will be seen the arrangement of keel blocks and bilge blocks. The keel blocks are to be of oak 12 x 16 inches x 4 feet long and are to have a height of 4 feet. The bilge blocks are to be on about 12-foot centers and operated according to the usual American practice by means of a galvanized chain on the floor of the dock and a leading rope through 6-inch sheaves secured to the wing near the deck, leading up and returning over the pipe railing around the tops of the wings. The return rope leads to the tail dog and is used in tripping the dog and pulling the block out when the ship is leaving the dock. The bilge blocks are provided with an elevating screw which has been found to be of great service for removing blocks one at a time for painting.

In the American practice of handling floating dry-docks, side shoring is not used. There is a general practice, however, of using centering trams for locating and steading the vessel in position until firmly at rest upon the keel and bilge blocks. The arrangement of these trams can be seen in Plate 112, showing the general design of the dock.

ILLUSTRATIVE DISPLAY DRAWING.

There is also submitted herewith, an illustrative display drawing or perspective view (Plate 117), carefully prepared as to relative scale and proper angular projection from the plans, the background being worked in from actual photographs taken approximately from the viewpoint of the illustration.

The vessel as shown, requiring the full lifting power of the dock, is the Minnesota, and lying alongside, to convey more clearly the scale of the structure, is shown the new steamer Prince Rupert of the Grand Trunk Pacific Railway, now running between Prince Rupert and Vancouver.

While such a drawing is unusual, its value as a ready means of conveying information must be apparent to all. The use of similar illustrative plans is customary with architects, and it is believed that the practice may be adopted to advantage by engineers generally.

DISCUSSION.

THE PRESIDENT:—You have heard the paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Mr. F. E. Kirby and Mr. W. T. Donnelly. The paper is now open for discussion. This is certainly a most instructive paper, and when one considers that Prince Rupert is some five or six hundred miles north of Vancouver, where you would think the ice grew all the year around—but it does not—certainly the project is a most remarkable one.

I regret our Honorary Member, Sir William Henry White, who has just returned from Prince Rupert, is not here. If he were here he could tell us the story of the new Pacific road on the project at Prince Rupert, which would be certainly very interesting.

MR. JOHN REID, *Member:*—I would like to ask Mr. Donnelly where he puts the crane for getting machinery, or parts out of the machinery, which is on the dock. I do not see any provision for lifting boilers, or engines, or shafting from the ship.

MR. WILLIAM T. DONNELLY:—While not referred to in this paper, there is to be a 50-ton crane at the head of the pier. It would not be desirable to take the machinery out of a vessel while in a dry-dock. The removal could be accomplished much more easily with the ship lying alongside the pier.

I should like to make a slight addition to this paper relative to the security of the dock against loss by sinking. About the time of the sinking of the dock Dewey, I was engaged in determining the actual structural weight of the metal in the wings and the amount of buoyancy due to the wooden pontoons when full of water. It then developed that the weight of the wings, including the machinery, would not be sufficient to overcome the buoyancy of the pontoons when full of water; that is, it would be necessary to add ballast of some kind to cause the dock as a whole to sink.

In reviewing this condition in my mind, it occurred to me that it might be possible to so arrange the ballast that it might have the opposite effect after the

dock had been lowered to its greatest working depth; that is, the depth which would take over the keel blocks, the greatest draft for which the dock was designed. This resulted in providing the extra ballast amounting to about 375 tons, in the form of timber (see Plate 114) to be placed in the wings upon the flooring about 7 feet below the top. The displacement of this amount of timber will represent about 650 tons and, of course, its submergence by the sinking of the dock would increase the displacement to this amount, and if the necessary weight to sink the dock was only 375 tons, all of this displacement would be reserved buoyancy, and it would be practically impossible to cause the dock to sink entirely.

It will be seen that this security would depend upon the nature of the material used and not at all upon any structural feature. In other words, the dock might be injured in any conceivable manner and it would still be impossible to entirely submerge it.

THE PRESIDENT:—Is there any further duscussion? Any other questions to ask? If not, I will extend in your behalf the thanks of the Society to Messrs. Kirby and Donnelly for their admirable paper, and we will pass to the next paper, entitled "Heavy Oil Engines for Marine Propulsion," by Mr. G. C. Davison, Member. In the absence of Mr. Davison, the paper will be read by Mr. Reid.

MR. REID:—I would be very much better pleased if Mr. Davison had turned up to read his own paper. I am instructed to curtail the paper, and may leave out the matter which he would wish to emphasize. However, I will do my best.

Mr. Reid then abstracted the paper.

HEAVY-OIL ENGINES FOR MARINE PROPULSION.

By G. C. Davison, Esq., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

The technical press of the world for the past two or three years has contained much on this subject, and at the present time general interest is still on the increase. This may be accounted for by the fact that we have a large cheap supply of liquid fuel available, and that its use for the propulsion of vessels is attended by wonderful military and commercial possibilities. Therefore, the subject is one which is worthy of the attention of all naval architects and marine engineers.

Within the past few years there have been various types of engines developed for the purpose of using crude oil, or fuel oil. These engines may be divided into two general classes—those working on the constant volume, or Otto cycle, and those working on the constant pressure, or Diesel cycle. The Otto cycle is too well known to require a description here, since it is the cycle used in all gasoline and gas engines. Its use is practically limited to volatile fuels and gases. Kerosene and the heavy hydrocarbons have been used to a limited extent in engines of the Otto principle by vaporizing the fuel oil by means of heat. But up to the present, little practical success has rewarded the efforts made in this line.

The Diesel engine, on the other hand, has been a success from the first as a heavy-oil engine. Its use was at first limited to stationary engines. Success has been so marked that the increase in the output of these engines has been remarkable since its first development. Only in the last few years has it been considered as a marine engine, but it has shown itself so well adapted to marine propulsion that its use afloat has rapidly grown so that at the present time it is estimated that over 250 sea-going vessels of from a few hundred to several thousand tons each, are now equipped, or being equipped, with these engines.

The Diesel cycle may be briefly described as follows:

1. On the admission stroke pure air is drawn into the cylinder.

2. On the compression stroke, the pure air is compressed to a pressure of about 500 pounds per square inch. Due to such a high degree of compression the air is heated to about 1,000° F.

3. At about the beginning of the return or expansion stroke the liquid fuel is sprayed through a specially designed valve, into the hot compressed air. Due both to the high pressure and the high temperature, the small particles of fuel are burned almost instantly, thereby increasing the temperature and maintaining the pressure about constant during the first part of the stroke. Fuel is sprayed in until enough has been supplied to enter into combustion with the oxygen of the air. When this point is reached, usually at about one-tenth the stroke, the fuel valve is closed and during the remainder of the stroke the hot products of combustion expand, doing work.

4. On the next stroke the products of combustion are expelled.

Typical indicator cards of both the Otto and the Diesel cycle are shown in Figs. 1 and 2, Plate 118.

The cycle above described is the usual four-stroke cycle, and is the one on which the engine was first developed, and hundreds of thousands of horsepower are in use to-day. It has certain advantages as well as disadvantages.

The Diesel cycle is also used on the two-stroke principle as is the case with engines of the Otto cycle, but here again the Diesel cycle has a great advantage. During the process of scavenging at the end of the expansion stroke the Otto cycle, employing a mixture of air and fuel, loses a part of the unconsumed fuel through the exhaust ports. The Diesel type of engine, on the other hand, is scavenged by a charge of pure air and, therefore, no fuel is wasted in this way. The fuel does not enter the cylinder until after the end of the compression stroke, and every particle of fuel injected is burned in the cylinder.

From the foregoing it will be seen that the main points of difference between the Otto and Diesel cycle may be summarized as follows:

Fuel.—The Diesel engine may employ practically any form of combustible liquid, while the Otto cycle must use a gas or vapor.

Compression.—Theoretically, the higher the compression, the greater the efficiency. There are certain practical limits to this, and the Diesel engine is enabled to attain this limit since only pure air is compressed. In the Otto cycle the compression is limited by the danger of premature explosion due to raising the temperature of the mixture by compression.

Explosion.—Since the fuel is sprayed into the Diesel engine at a rate just sufficient to maintain a constant pressure, there is no explosion and, consequently, no sudden shocks, nor instantaneous changes of temperature. This is conducive to smooth running and long life of working parts. The Otto cycle, on the other hand, is based on an explosive action.

From the foregoing it is seen why the Diesel type of engine has shown itself so well adapted to the use of heavy oils.

Mechanically there are other advantages peculiar to the Diesel type, such for example as absence of an igniting device—absence of a carburetor, or vaporizing device, all of which are delicate affairs and give the greater part of the trouble experienced with explosive engines.

A complete Diesel engine requires certain auxiliaries. These are the air compressor, the fuel pumps, a lubricating pump, and a water circulating pump. The last two mentioned auxiliaries are also found on all engines of the Otto cycle.

The air compressor is usually built in two stages, though some designers prefer three. Two stages seem ample as the maximum air pressure used for spraying the oil into the cylinders is seldom in excess of 1,000 pounds per square inch. In engines of a few hundred horse-power it is customary to use only one compressor, on the same bedplate with the engine, and driven from a crank on the main shaft. There are no novel features in connection with the design of these compressors.

The fuel pumps are always attached to, and driven by the main engine. It is the usual practice to supply a separate pump for each cylinder, but it is possible to operate two or more cylinders from one pump.

The governing of the engine is accomplished by controlling the amount of fuel delivered by the fuel pumps to the spray valves. In this way the fuel is practically measured out for each stroke by the pump, and very accurate control is possible. There is no throttle valve employed on these engines. The amount of air taken in and compressed on each stroke is the same. At half load, for example, only about half the amount of fuel is delivered. This fuel burning in an excess of oxygen is completely consumed and imparts all its heat to the contents of the cylinder. Hence, the engine is efficient at reduced loads, and is as flexible as any type of internal combustion engine. Governing of these engines is merely a question of fly-wheel and number of cylinders. A recent test of a two-cylinder stationary engine, having a coefficient of fluctuation of one-ninetieth showed a variation in speed of 2 per cent. from full load to no load.

The relative advantages of four-cycle and two-cycle marine engines may be summed up as follows:

Economy.—The four-cycle has about 8 to 10 per cent. less fuel consumption than the two-cycle. Taking an average case, a four-cycle engine would use only 0.46 pounds per horse-power-hour, while a corresponding size two-cycle engine would consume 0.50 pounds of fuel per horse-power-hour. This is the principal advantage of the four-cycle over the two-cycle, but advocates of the latter type believe this difference in fuel consumption will soon be reduced.

Heat Conditions.—The four-cycle engine has the advantage as regards the cooling of pistons and cylinders, but loses some advantage by having an exhaust valve in the head exposed to hot exhaust gases.

Turning Moment.—The two-cycle is much superior, requiring a very much smaller fly-wheel. Six-cylinder high-speed engines require no fly-wheel.

Reversibility.—The two-cycle is again superior, first, because the same valve gear may be used both in the ahead and astern directions, thereby simplifying the construction; second, because for a given engine twice the number of cylinders may be brought into action; and third, because of less inertia, due to reduction in weight of fly-wheel, the engine will respond quicker.

Weight.—The two-cycle naturally has an advantage.

Space.—Again the two-cycle has the advantage, due to its nature.

It seems to be the general opinion of authorities on the subject, that for marine purposes, the two-cycle is superior to the four-cycle engine. For marine purposes, the superior economy of the four-cycle engine has to be balanced against the even turning moment, the simplicity, the reversibility, the lightness and the compactness of the two-cycle engine. If, as many engineers confidently expect, the economy of the two-cycle can be made the same as the four-cycle, there will be no room for argument.

Considering the present development of the two types, the question, as applied to stationary engines, assumes an entirely different aspect. Here we are not greatly concerned with questions of weight, space and reversibility. This gives the four-cycle engine, due to its superior efficiency, the leading place. Consequently, practically all stationary oil engines at present are of the four-cycle type. It remains to be seen whether they will maintain this position. If the economy of the two-cycle engine is improved, as many expect, the question for land installations will then hinge upon the cost of manufacture. When this time arrives it is probable that the two-cycle engine will become the favorite for land, as well as sea.

Going further into the development of oil engines, we come to double-acting types. There are now in successful operation, horizontal, four-cycle, double-acting, tandem engines developing 500 horse-power per cylinder. Their use is at present limited to land installations.

The vertical, two-cycle, double-acting engine for marine purposes is the latest development. Several engines have recently been completed and tested. The smallest of these develops 300 horse-power per cylinder, and the largest 2,000 horse-power per cylinder.

A natural advantage of the double-acting engine is that it permits a reduction in weight per horse-power. An alternative advantage is that for

a given weight per horse-power it permits of a reduction in piston speed, and, consequently, of a slower number of revolutions and of a larger and more efficient propeller. As it happens, the first large marine, double-acting engines have taken advantage of the latter in preference to the former feature. When applied to large ocean going steamers where the question of weight and space is not of paramount importance as compared to reliability, the builders of these recent engines appear to have been wise. Even with the comparative low piston speed and massive parts, there is a saving in weight and space as compared with the usual steam plant for the same class of vessel. It is interesting here to note that the owners of two of these large vessels have had occasion to complain of the small space occupied by the engine, slow and strong as it is, because of the rules for measurement for tonnage and consequent dues. This, of course, is only a passing phase of the problem and is only another instance of the case where engineering developments are ahead of the laws and customs.

THE MECHANICAL PROBLEMS CONNECTED WITH HEAVY-OIL ENGINES.

In general the mechanical problems which have been met and solved in Diesel engines are of the same nature as those encountered in large gas engines. In fact, the firms which have done most to develop the oil engine have had a wide experience with gas engines, and utilized much of the knowledge thereby acquired, in their oil engine construction.

The problem of dealing with heat in cylinders and pistons is dealt with as in gas engines. In large marine engines the latest tendency is to cool the pistons by means of circulating oil in their heads. The heated oil on leaving the pistons is passed through a cooler, consisting of a nest of tubes around which cooling water is circulated. The reason for using oil as a cooling medium instead of water is that slight leakages in the flexible connections is not objectionable, and would not interfere with the lubrication of working parts. Oil, however, is not as good a conductor as water, and also has a much smaller specific heat.

Materials.—In the earlier types of Diesel engine the columns, bedplates, cylinders and water jackets were made of massive cast iron. This insured ample strength and durability, but made the engines very heavy, some of them weighing as much as 400 pounds per horse-power. As these earlier engines were used on land only, there was and is no objection to their heavy construction.

When the attention of marine engineers was directed toward heavy-oil engines, radical changes in construction were at once inaugurated to adapt

them for use on board ship. As a result a number of firms have produced engines which are amply strong, and yet lighter in weight than the lightest steam plants afloat. The lightest engine which has been built weighs only 20 pounds per horse-power. In this engine the bedplate and housing were aluminum, the crank-shaft and connecting rods of special high-grade steel, the water jackets of copper, and the cylinders and pistons of cast iron.

Certain four-cycle marine engines have been constructed up to 1,000 horse-power, and weighing from 40 to 60 pounds per horse-power. In these engines cast steel bedplates, and cast, or built-up, steel housings have been used. In these, cylinders and pistons are the only cast iron parts. These engines have demonstrated that they are amply strong and durable.

Many two-cycle marine engines, ranging from 150 up to 2,500 horse-power have been built, in which the weight is not more than 40 pounds per horse-power. In these, high grade bronze castings are employed for bed-plates and housings.

Piston Speeds.—The lowest speeds used are about 600 feet per minute in very heavy slow-running engines. The highest speed in the lightest types is 1,100 feet per minute. For ordinary work it is perfectly safe to use a piston speed of 1,000 feet per minute, as has been found to be the case in steam and gas engines.

Lubrication.—In practically all marine oil engines some form of forced lubrication is used. Babbitted bearings are used throughout. Little or no trouble has been found with bearings. Due to the high pressures used, the bearings are somewhat larger than in steam engines of the same power.

Piston Packing.—The same form of ordinary split rings are used as in ordinary gas engine practice. On account of the higher pressure a greater number of rings are employed in oil engines.

Stuffing Boxes.—For double-acting engines of this type a special form of metallic packing for stuffing boxes has to be provided. The usual forms of metallic packing used in modern steam engines are inadmissable, both on account of the high pressure and temperature. This problem has, however, already been successfully solved.

To sum up the only problems which have had to be solved are those due to the high pressure and temperature in the cylinders. All these problems have been successfully solved so that there are now fully a score of different designs in successful operation. From this it should not be assumed that these practical problems are easily and cheaply solved. Their solution represents years of expensive experimental work on the part of manufacturers who naturally retain for their own use the practical knowledge thus derived. Ordinary steam engine and gas engine practice cannot be followed without some modification.

Sketches accompanying this paper illustrate the principal features of engines of the Diesel type. Space will not permit entering into a detail discussion of special features.

Tests.—Many tests have been made, with various types of these engines, and have been given in the technical press of the world. The most important results are in connection with fuel consumption. These show an extreme range from 0.4 to 0.6 pounds fuel per horse-power-hour. Some of these tests have extended over several weeks of continuous running on the test stand. The results of recent voyages of ships fitted with these engines have demonstrated the remarkable fuel economy obtainable.

EXTENT OF USE OF OIL ENGINES FOR MARINE PURPOSES.

It has been estimated that over 250 vessels in the world are to-day fitted with oil engines. Submarine torpedo boats form a large part of this number. These vessels usually have from 600 to 2,000 horse-power. France is now constructing submarines having two oil engines of 2,500 horse-power each. Russia has had gunboats of 600 horse-power each for several years. Italy is building a torpedo boat destroyer equipped entirely with oil engines. England has ordered a destroyer having an oil engine for cruising purposes and steam turbines for high speed. Germany is reported to have an engine of 12,000 horse-power for use on one of her latest battleships for cruising purposes. Austria has a cruiser with two 900 horse-power two-cycle engines. The foregoing does not pretend to be a complete list of what foreign navies have already done in connection with these engines.

In the merchant marine the following instances may be mentioned:

In Russia a number of tank steamers have been running on the Black Sea for the past few years, using oil engines of about 600 horse-power.

In France the barque Quivilly, fitted with two 300 horse-power Nuremburg engines, has crossed the Atlantic three times and her engines have been pronounced a great success. The owners of this vessel are now building another ship to be fitted with still larger engines. Other vessels with oil engines are in daily use in that country.

In Germany the firm of Blohm & Voss has already finished a 7,000-ton ship to be equipped with two engines of 1,000 horse-power each. These are the first double-acting two-cycle oil engines ever built, having been designed by the Nuremburg branch of the Maschinenfabrik Augsburg-Nürnberg A. G. One of these engines was built by Messrs. Blohm & Voss, the other at Nuremburg. These engines are heavy and strongly built and run at a slow speed—125 revolutions per minute. These engines have but three working cylinders.

On account of the success obtained with these engines Messrs. Blohm & Voss are now building a cargo vessel of 11,000 tons. The engines for this ship are of 1,500 horse-power each, and work on them is well under way.

In England and Holland a number of large vessels propelled by oil engines have already been built and others are building, but space will not permit of a further discussion of this phase of the subject. Considering the short time in which this development has taken place, it appears truly remarkable.

THE ADVANTAGES OF HEAVY-OIL ENGINES.

In view of the rapid progress, and the world wide interest in this new engine, some of its leading advantages are here reviewed, and will fully explain why it is considered such an important matter.

Economy of Fuel.—Under ordinary conditions a vessel propelled by steam will consume about 2 pounds of coal per horse-power-hour. In daily practice, due to unfavorable conditions, such as bad firing, inferior qualities of coal, leaky valves and pistons, etc., the consumption frequently exceeds 3 pounds of coal per horse-power-hour. The oil engine consumes about one-half pound of fuel per horse-power-hour. The variation from this amount is slight. For large engines under certain conditions the consumption would be slightly less. Generally speaking, as extreme limits, the oil consumption may be said to vary from 0.4 to 0.6 pounds per horse-power-hour. Therefore, for a given weight of fuel a ship propelled by oil engines would have from four to six times the radius of action of a similar ship propelled by steam. From a military point of view this advantage alone is so overwhelming as to force all navies to eventually adopt oil fuel for the fighting ships of the future. Aside from the military advantage of increased cruising radius there is a decided commercial advantage resulting from fuel economy. The extent of this advantage is a mere matter of arithmetic, depending on the relative cost of oil and coal in the port from which the vessel operates. On the Pacific Coast of the United States for example, with coal at $8.00 a ton, and fuel oil at two cents a gallon, the cost of coal per horse-power-hour would be 0.71 cents, while for oil it would be only 0.133 cents. That is, for this locality the cost of coal for motive power would be five and three-tenths times as much as the cost of oil for the same power. In Europe, and on the Atlantic Coast of the United States, the difference in the cost of fuel is so much in favor of the oil engine as to cause the latter to receive serious consideration at the present time. Generally speaking, the cost of fuel on the Atlantic Coast is such as to make the fuel bill of the oil engine plant about half that of the steam plant.

Attendance.—The economy in the cost of fuel is but one item in the total saving due to the use of oil engines. In general terms it may be stated that the cost of attendance of a heavy-oil engine is about half that of a steam plant of the same power. The expenses due to water tenders, firemen and coal passers is entirely eliminated. Due to the absence of these persons on board a ship there is an incidental saving of space in the living quarters, which would prove of considerable value in any vessel, and especially in a naval ship.

Weight.—As regards the item of weight of plant, exclusive of fuel, the advantages are all in favor of oil engines. Comparing light class installations, the steam plant will weigh about 60 pounds per horse-power, while the oil engine will weigh less than 40 pounds per horse-power. Taking heavier installations, as in a merchant vessel, the difference is still more striking, the oil engine weighing from one-half to one-fourth of the steam plant of the same power.

Space.—As regards space occupied, the oil engine will require less than half that occupied by a steam plant. This applies to both heavy and light types of oil engines when compared with heavy and light types, respectively, of steam installations.

Endurance.—To maintain full speed for considerable lengths of time on naval vessels propelled by steam involves such strenuous work on the part of the fireroom force that as a matter of fact very high powered vessels, such as destroyers, seldom if ever have been able to make a run at full speed corresponding in length with the total fuel supply. With oil engines, however, there being no fireroom force, this drawback does not exist. The engines are designed with a view to continuous running, and aside from the extra vigilance which any engineer would naturally give his engine when running at full speed, no extra strain or hardship is inflicted upon the personnel.

Repairs.—The yearly average cost of repairs is much less for an oil engine plant than for a steam engine plant. This follows from the fact that not only are the boilers and their auxiliaries eliminated, but also important auxiliaries such as condensers, and air pumps, disappear with the adoption of oil engines. The latter have only three small auxiliary pumps, usually driven by the engine. These are the water circulating pump, the lubricating pump, and the fuel pump. On account of the consequent simplicity of the oil engine plant, regarded as a whole, with the consequent reduction in the number of parts, it is easy to see why there should be such a great reduction in the cost of repairs.

Reliability.—In an oil engine, each cylinder is in many respects an

independent unit. Not being dependent upon so many external units such as boilers, feed pumps, condensers, air pumps, lines of steam piping, the probabilities of any accident external to the engine causing the plant to stop, are very remote in comparison with the steam plant. In the event of an accident to one cylinder such as a fracture, such cylinder could be run idle while the other cylinders would independently develop their power.

Absence of Smoke.—This is a purely military advantage, much sought after but not heretofore obtained with coal. With oil engines there is a complete absence of smoke.

Funnels.—In a war vessel, it has been found that unprotected funnels are a great menace in action. With the oil engines, the need for a funnel disappears.

Cleanliness.—Having no coal smoke nor cinders, a vessel using oil engines would be as easy to keep clean as one of the old sailing ships.

Readiness for Action.—With modern water tube boilers and turbines it is still necessary to spend about an hour getting up steam, warming the engines, etc., before the vessel is ready to move. With oil engines, none of these preparations are necessary. The engine is ready to run at a few seconds notice.

Time for Loading Fuel.—To coal a war vessel quickly is of such paramount importance that it is now the custom to make an evolution of this event, the services of every officer and man of the crew being required. But in spite of this, coaling is still a matter of one or more days. With oil fuel, it ceases to be a matter of manual labor but is dependent solely on the equipment used—on the pumps and sizes of piping used, and with any vessel could be easily reduced to a matter of an hour.

In order to illustrate the above-mentioned advantages by a concrete case, we shall take the United States Destroyer Paul Jones, a complete account of which will be found in the Proceedings of the American Society of Naval Engineers, Vol. XIV, No. 3.

This vessel has been selected as an example, primarily, because she is a very successful high powered coal burning destroyer, and represents the most economical and efficient installation of coal burning water tube boilers, and reciprocating steam engines. By taking a vessel of this type for comparative purposes, it is believed that we can make a short cut, because we are comparing the most efficient and lightest type of marine steam plant with an engine of the future. Of course, we realize that we have a later type of destroyer which uses oil fuel under its boilers, and is driven by steam turbines. With this later installation, there is a certain amount of saving of weight as regards machinery, and a difference of economy, a slight gain

at full power and a loss at the greatly reduced power of cruising speeds. To enter fully into the question would be to take up a very warm present-day discussion which has nothing to do with internal combustion engines. Therefore, it is preferred to make the comparison on the basis of coal burning boilers and reciprocating steam engines as opposed to the internal combustion heavy oil engines. After all, the comparison boils itself down to steam versus oil engines.

The principal data of the Paul Jones are as follows:

Length	250 ft.
Beam	23 ft. 6 in.
Draft (mean)	7 ft.
Displacement (sea-going trim)	470 tons
Coefficient of fineness	0.41

There are four Thornycroft water tube boilers designed for a working pressure of 300 pounds per square inch, each boiler capable of developing 2,000 horse-power.

There are two engines of the four-cylinder vertical triple expansion type each of which will develop about 4,000 horse-power.

The usual auxiliaries are of modern approved types and are excellent in every respect.

With this steam equipment the Paul Jones gave most satisfactory service on her official trials, and has continued to do so in regular service. The most serious criticism which may be made of this type is its inability in times of emergency to make prolonged runs at maximum speed. Granting an engineer's force efficient enough to maintain the machinery in proper condition for such a severe test, the complement allowed is so limited that the use of the total fuel supply at full speed is practically impossible. As a matter of fact not one coal burning destroyer of this type, has, during the past seven or eight years, the period of their existence, ever made a prolonged run at full power, consuming its total fuel supply. In cruising the economical speed of these vessels has been found to be at or below 10 knots, due to the economy of the engines at low speeds. Occasionally one of these vessels will make a prolonged run at a little over 20 knots, but even then they are running with only a fraction of their maximum power.

With a complete knowledge of what high powered vessels of this type will do under practical conditions, it is interesting to try to discover what they would probably do if their entire steam plant were removed, and replaced by internal combustion oil engines.

It so happens that a certain type of two-cycle internal combustion engine has already been designed, and is now building for a foreign naval power. Complete plans and data for this are available, and it happens to fit so well into the type of destroyer in question that this actual engine has been selected in preferance to a theoretical engine designed for the particular purpose. It is possible that a specially designed engine might prove of less first cost, and effect a greater saving of weight and space. But since we are dealing with an actual vessel it is preferred to take an actual engine. Even so the results obtained are sufficiently startling.

The engine which has been selected is of the Nuremburg type. It is of eight cylinders, single-acting and two-cycle. The general dimensions of the engine are as follows:

Diameter of cylinders	18.9	in.
Stroke	19.7	in.
Revolutions per minute	350	
Brake horse-power	2,500	
Length overall	34	ft.
Breadth	5	ft.
Height	10	ft.
Weight complete	47	tons

The eight cylinders give perfect balance and an evenness of turning moment not surpassed by the steam engines.

Three of these engines will be used. They will be installed as shown on Plate 127. The present steam installation of the Paul Jones is shown on Plate 126. The unassigned space shown on the plans represents only a part of the space saved. The rest of the space saved is in the engine rooms and fuel storage.

Three of these engines will have a shaft horse-power of 7,500 which is somewhat in excess of the shaft horse-power of the present steam engines rated at 8,000 indicated horse-power.

For such a high-powered vessel, which would be expected to cruise long distances at an economical speed there are reasons which would make the selection of three engines preferable to two larger ones. By uncoupling the two-wing propellers the middle engine could be used for cruising purposes and even then, running at half power with a very economic fuel consumption, would give a cruising speed of 16 knots per hour. In this connection the propeller question has been carefully looked into and shows that the proposed plan is thoroughly possible with but a slight loss of propulsive

efficiency. With the proposed installation we would have a destroyer ready at a minute's notice to proceed at full speed, with a complement one-half that now carried, with a radius under all conditions of from four to six times that which we now have, and with a total annual expense far less than that of any vessel of the same power in the Navy to-day. Instead of dwelling further on these advantages, the following table of actual figures, showing the difference between steam and oil engines, has been compiled:

TABLE.

Item.	Steam.	Oil.
Indicated horse-power	7,700	8,300
Shaft horse-power	7,000	7,200
Weight of main motive power machinery	449,522	317,000
Weight per shaft, horse-power, pounds	64	44
Cruising radius at 16 knots with 180 tons fuel, miles	1,700	10,000
Pounds fuel per horse-power-hour at 16 knots	3.0	0.60
Cruising radius at 28 knots with 180 tons of fuel	630	2,950
Pounds, fuel per horse-power-hour at 28 knots	2.34	0.50
Engineer's force required	54	21
Fuel consumed per annum 20,000 knots cruising, tons	2,100	360
Fuel consumed in port, tons	300	300
Annual total fuel consumption, tons	2,400	660
Cost of fuel on Pacific Coast	$19,200	$4,620
Pay of engineer's force per year	22,500	9,600
Repairs, average annual	10,000	2,000

In the foregoing the question of main motive power only has been considered. But, to make the vessel thoroughly comfortable and practicable, certain auxiliaries have to be provided. The auxiliaries of the main engines are few and simple and as a rule are direct driven from the engines. There remains then only exterior needs to be provided for, such as cooling, heating, lighting, anchor hoist, steering engine, etc. One solution would be to provide a small donkey boiler using liquid fuel. Another, and more attractive solution, is to provide two auxiliary engines of 100 horse-power each. These would be direct connected to generators which would supply sufficient current for all purposes required. This system would be quite efficient even taking into consideration the question of heating, and has much to recommend it in preferance to the donkey boiler. In extremely cold weather the heat obtained from the jackets and exhaust of the auxiliary

engines could be used for heating purposes in addition to the electric heating, thereby producing an economy in excess of any steam heating plant.

It will not be long before high powered vessels equipped with internal combustion engines, as above described, will become familiar objects. To say nothing of modern developments in the merchant marine, and of the installations on submarine boats of to-day, destroyers have already been ordered which virtually fulfill the foregoing description. According to accounts Italy has recently ordered a destroyer equipped with internal combustion engines while England has ordered one to be built by Thornycroft, in which there will be an internal combustion engine on the middle shaft for cruising purposes while the outer shafts are driven by steam turbines.

DISCUSSION.

THE PRESIDENT:—Gentlemen, you have heard the paper on "Heavy Oil Engines for Marine Propulsion," by Mr. G. C. Davison, which has been presented by Mr. Reid. Is there any discussion on this paper?

MR. R. C. MONTEAGLE, *Member:*—The subject of this paper is one of great interest to all, and therefore it is in order to inquire as to some of the statements made therein.

First. At the present time I would ask if there actually is a large supply of liquid fuel available, as stated, and at a price within commercial reach? From all I can learn, this is not so in the East. Were the supply in excess of the demand, the price would undoubtedly have been lowered during the past few years. But the price of fuel oil has increased during the past two years, from 88 cents per barrel, to 98 cents per barrel at the present time in New York City, and in Boston to $1.10 per barrel. The reason for this is simply that there is not enough oil to supply the demand, and it has been stated to me on the authority of 26 Broadway that, if the supply were great enough at moderate price, the use of oil fuel in the stationary plants of New England would proceed as rapidly as they could be installed.

Second. With regard to the compression of 500 pounds named, I would ask if this is not much less than in the original Diesel engine, and if so, if nothing has been sacrificed in economy by such reduction of compression. Pure air only is compressed—why should the limit be placed at 500 pounds?

Third. I do not agree with the author that for ordinary mercantile work in the case of steam engines, a piston speed of 1,000 feet per minute is perfectly safe. It is not, as general practice proves, and I doubt very much whether it is perfectly safe in the case of heavy oil engines, under constant running conditions.

Fourth. It would be interesting to know how the author arrived at his figures for annual repairs as between a steam plant and an oil engine plant, viz., $10,000 for steam and $2,000 for oil. It is absolutely necessary in heavy oil engines to have the most excellent workmanship, for instance, and nothing but ground joints must be used. Should any trouble be experienced with these, how far would $2,000 go in repairing an 8,300 horse-power plant? It should be noted, also, that in case of steam, there are two line shafts, stern bearings and stuffing-boxes, propellers, etc., while in the oil plant there are three, giving opportunity for trouble to the extent of one-third more than with the steam plant.

Mr. Clinton H. Crane, *Member:*—It is rather a thankless task to take the position of a knocker, but the Diesel oil engine, or the Diesel engine to burn oil or coal dust, has been before the engineering profession for more than fifteen years. During that time we have seen what has happened to the turbine. Almost all that we have read or heard about the oil engine has been what somebody says that somebody else did. The writer speaks of engines with a capacity of 2,000 horse-power per cylinder having been built. He does not state when or where.

I think there undoubtedly exists in the mind of any engineer the opinion that the difficulties, when you come to deal with 500 pounds pressure, are very greatly increased. The limit on the size of a reciprocating engine seems to me not to be a question of horse-power, but a question of maximum pressure. The strength of cranks, the amount of crank pin bearing, the strength of connecting rods, are all determined, and must be determined on this question of maximum pressure. That is an inherent disadvantage which any engine with a maximum pressure as great as shown by this oil engine diagram labors under.

In the 4-cycle type, which the author says is more economical, one stroke in four is a power stroke. Therefore in a steam engine of the same cylinder capacity, the same power can be produced with one-quarter of the mean effective pressure.

It seems to me that the oil engine has so many possibilities in the smaller field that the people who put forth the claim for the use of the oil engine on battleships, for large sized steamers, are hurting their own development. We know what a gas or gasoline engine has done up to 300 horse-power and even in those relatively small powers we have a multiplicity of cylinders. With anything like a large installation, with an oil engine, the multiplicity of cylinders and the care of those cylinders is bound to increase.

Another point which the writer of this paper has not enlightened us on are the points where we may look for trouble. In talking to users of the smaller sized Diesel engines, when you finally pin them down to it, there is some little piece here, there is some little piece there, that has got to be renewed once a month, or that has got to be taken out and cleaned every four or five days—all those things are necessary to a new development, but they are things which, as engineers, we should be informed of by the writers of such papers.

If the oil engine is to take the place of the steam turbine, a great deal of develop-

ment not only in the manufacture, but in the design, must take place, for we have got to train an absolutely new corps of men to operate our machinery. If our steam engineer gives us trouble, all we need to do is to hire a new man. That was true ten years ago with the gasoline engine of small power. One of the great sources of trouble, one of the reasons why ten years ago the gasoline engine was not a successful unit, was the fact that the men were not trained to run it. To-day, up to 100 horse-power, I think we can say the gasoline engine is a success as a marine engine. There are a few units running of larger dimensions, but I challenge the statement that as a successful prime mover you can use large powers. It seems to me that those who are familiar with the Diesel engine in this country can very well afford to inform us on the points where we may look for trouble, because those points do exist.

THE PRESIDENT:—I shall have to ask those who discuss this question or any of the other papers which follow, to make the discussion as brief as possible. The hour is growing late.

MR. A. GEORGE MATTSSON, *Member:*—Judging by the remarks of the last speaker, perhaps we have already overcome the troubles in oil engines installed in vessels, and in case we have not there is certainly hope that it will be done in the future.

It strikes one quite forcibly regarding some of the statements as to the cost of fuel. For instance, on the Pacific coast, the cost of coal is given as $8 per ton, and that of fuel oil as 2 cents per pound. Now, comparing these prices with those existing in the Great Lakes district, where the price of coal is $2.75 per ton, we can readily see what an enormous difference there would be in the economy in using oil instead of coal in different localities.

Secondly, when we consider the question of auxiliaries, taking for instance, a freight ship with 1,800 indicated horse-power, we often have auxiliaries amounting to 300 indicated horse-power, and the question thus arises, what kind of motive power should we have to run these auxiliaries? It is suggested to have a donkey boiler, and it should be one of fairly large dimensions, and in such a case, we have the complications arising from two systems in the same ship. Even if we have overcome the difficulties of the Diesel engine itself, employed as a prime motor, the complications of driving the auxiliaries have been such a factor that very little consideration has been given to the employment of the same in the Great Lakes district.

MR. THEODORE LUCAS, *Member:*—Mr. Crane asked for some particulars from someone as to the experience with the Diesel engine. It has been my privilege to be for two years with the Diesel Engine Company, handling new business and a large amount of repairs and replacements, and it is my pleasure to present to the Society some experience in connection with a good many parts, and point out where these difficulties may occur.

I would like to say, also, in a general way, that these difficulties were entirely of a mechanical nature, and that by superior workmanship, and the use of very high

grade material, that these difficulties can be readily overcome, and without doubt, when the builders realize this, there is a possibility that this engine will supplant everything else.

I would like to point out that the fuel pump is one of the most serious points that has to be considered. It has been found that ordinary bronze or cast iron is not nearly good enough for transmitting the oil to the high pressure cylinders. It is necessary to take forged steel, if not a high grade of nickel or vanadium steel, and forge the barrels of the pumps, so that the walls are absolutely solid and without porosity. The valves themselves should be ground and should be so readily accessible that they can be overlooked on a minute's notice. It is always necessary to provide not only one valve in the suction or discharge lines, but to provide two, and even three sometimes. It is also desirable to put the pumps and valves as near to the fuel valves on the engine as possible.

Another point which causes a great deal of difficulty is the fuel needle. The fuel needle is very troublesome when it leaks, the flame will strike back and it becomes very hot, and sometimes spots will fuse on the atomizer on the inside, and also on the needle itself. It has been the practice lately to make the atomizers of bronze or brass on the inside of the point of the needle. It is desirable in these places to use a very high grade of steel, and it is possible that a construction can be found which will do away with the fuel needle, and that would be a very desirable thing to do.

Perhaps a good many of the members of this Society know that in Germany and in Europe in general, I believe, the so-called open-top atomizer has been developed within the last few years, and a great many designers since Litzenmayer have taken advantage of that, and prefer this construction at the present time. The oil is placed in a space permanently in connection with the compression space, and it is only air that is admitted by the needle. It keeps the needle back further from the point of compression and allows the air to cool the needle point. There are certain advantages in that arrangement, provided the oil flows very quickly and cleanly, so that no depositions of carbon can be formed in the open space.

The shafts are another thing that have troubled the designers greatly, and it should be aimed to make the shafts as rigid as they possibly can be made.

The disadvantage has been held up against the Diesel engine, that it is too heavy. I believe that careful designing and careful consideration of marine conditions can avoid almost entirely that difficulty. The Diesel engine offers itself by the handling of pure air for compression purposes only particularly to the 2-cycle and the double-acting type. It can be arranged very nicely, and I shall take the opportunity of forwarding to the Secretary a sketch that I have made of a Diesel engine, that shows fairly large size, 32-inch diameter, by 36-inch stroke, where all these difficulties can be overcome.

I prefer for the frame of oil engines of this high compression type a steel framing, which I believe is superior to a cast iron housing or frame, because the stresses are always direct tension or compression and therefore a steel column, securely

anchored at top and bottom, provides with the smallest amount of material and weight the necessary resistance to the stresses in the most direct and efficient form.

I believe that the designers of marine engines should attempt as much as possible to cut loose from stationary types, and to go back to what we call the standard marine type, which is being represented best in the torpedo boat engine. The starting is also a question that with Diesel engines has proved quite difficult, and this is due to trying to use the injection air at a pressure of 750 to 900 pounds per square inch for starting purposes. That means a very short discharge enters the cylinder at the beginning of the stroke, and then by its own expansion, gives the impulse to the piston for the farther movement down. I believe it would be found far more convenient and efficient to provide air at a lower pressure from the second stage—I believe 150 or 200 pound pressure would be far superior. The starting valves to be operated by some special form of a link, by which they could be cut in or cut out at the will of the engineer and by which they would have a late cut-off and a long stroke for receiving air from the reservoirs under full pressure. By this we have a much wider range for the starting and can do with less cylinders in this way than we would be obliged to have when we use the injection air at a high pressure during only a short part of the stroke.

I believe that double-acting engines with hollow piston rods and oil cooling can be provided in such mechanical perfection that there will be absolutely no difficulty experienced on the part of any good steam engineer with large marine practice. He would be prepared to handle it to best advantage.

In Germany at the present time a great many experiments are made with wood tar and gas tar, and all kinds of substitutes for fuel oil. All refuse of oil distillation can be used almost with entire satisfaction in Diesel engines, provided a small amount of warming is furnished, which is always available on board ship.

As to auxiliaries, I have developed a plan for providing a complete compressed air plant for distribution to all auxiliaries. I believe that everything could be done with compressed air to good advantage, and it would not be necessary to provide any special thing in the line of electric auxiliaries, except as they are needed for lighting purposes. I believe the modern turbine practice has shown that for rotating motors compressed air could be used in air turbines to good advantage and under quite good economy; at least the fans and centrifugal pumps could be supplied by compressed air turbines. The main thing is that the compressed air in this form would be less liable to freezing, and would be much more efficient and serviceable.

It is also possible to use pre-heating with the compressed air, readily affording the means to keep the freezing down and similar difficulties out of the way. It is also possible, I believe, in the form of the through-flow engine type which is occupying the attention of many engineers, to provide a high compression air engine that would compress the air to such degrees of temperature again that no freezing at any stage of the operation need take place in the cylinders. Such an air engine would be entirely alike to and compare well with the steam engine as far as handiness is concerned, and would be far superior to it in that it has no condensation losses.

Mr. Edward P. Robinson, *Member:*—I regret the absence of the author of the paper, because I think that if he were here he could throw light on certain parts of the paper which are not entirely clear. One of the things that occurs to me is the question of flexibility of the Diesel engine. In stationary practice this engine has proved itself very economical at full load, and it has also proved very economical at half load when running at full speed; but on a ship the conditions are different, because the power is reduced by reducing the speed of the engine. Now, if there is leakage of pistons or valves, the element of time affects this leakage, and it also affects the cooling of the compressed charge by the walls of the cylinder, and it appears to me that if you slow the engine down, as is at times necessary in marine practice, the compressed charge would not be hot enough to ignite the fuel. That is a point that I have not heard discussed anywhere, and it seems to me that it is of great importance. When the pistons and valves of the engine are tight, it may be possible to run the engine at very slow speed and still ignite the charge, but I should suppose that the leakage which is bound to come in service would seriously affect the ignition. If anyone can throw any light on that particular phase of the question, I should be glad to hear from him.

Mr. C. Lee Straub, *Member:*—In the parlance of the street, Mr. Davison's paper has only touched the "high spots" on this subject.

I have had the good fortune of examining several of the types of engines he compares with the steam equipment on the Paul Jones, and having been affiliated with the construction of a number of stationary American Diesel engines, feel qualified to criticise a number of items in the comparison.

The actual cost of repairs on Diesel engines exceeds the cost on good steam engines by fully 100 per cent. This is due to the exceedingly high pressures encountered in the Diesel practice and the multitudinous details encountered in the engine, oil service, and auxiliaries, such as air storage, etc. The particular type of Diesel engine referred to by Mr. Davison is installed in two 6-cylinder, 300-horse-power engines in the Quivilly. The cam shaft, air valves, oil valves, and in fact the prime operating mechanism, are all located on top of the cylinders. In order to remove a piston, all of this mechanism must be removed, and the cylinder must be lifted from the frame. This was of necessity required three times on the first two Trans-Atlantic trips of the Quivilly and as can be imagined, was on each occasion a big job at sea. I think that 300 to 350 revolutions per minute is too high for any commercial marine engine. Much of the gain of economy in the engine is lost in the necessarily inefficient propellers.

In the summary, the item of repairs, if properly kept, would exceed the $10,000 charged to the steam plant.

The average cost of fuel per annum, based on Atlantic coast costs, which approach more nearly the average cost of fuel oil, would be in the neighborhood of $9,000, based on the quantity stated as consumed.

I think that 500 horse-power per single-acting cylinder is about the maximum practical limit due to the heat conduction capacity of the cylinder wall.

The heavy oil engine for commercial, marine and naval propulsion, will undoubtedly be largely adopted in the near future, but I venture to predict that it will be in the form wherein much lower maximum pressures for both atomizing air and compression will obtain, where the mean effective pressure will be as high, the efficiency be as good, and the reliability of operation and repair cost much better than in any Diesel engine yet proposed.

Mr. John Reid, *Member:*—I think there is a danger, from the discussion which has already taken place, that the Diesel engine will not get fair play. There is no question but that Mr. Davison is very optimistic. There is a lot of trouble in connection with the Diesel engine. Mr. Crane, on the other hand, goes off in another direction, and evidently thinks there is no hope of the utilization of the Diesel engine at all. That is a mistake, because the Diesel engine has got to be reckoned with, and is coming along at a fast rate.

I would like to refer to an actual job that I had something to do with. The boat is a canal barge for the Canadian Lakes, 250 by 42.6 by 20 feet. She had 14 feet draft. There are two Diesel engines, reversible, of 200 horse-power each. That boat went across the Atlantic from Middlesburg to Halifax, and made good, but had all kinds of troubles. One of the troubles that these engines are going to meet is that the naval architect will not take hold of them and alter his ship to suit the Diesel engine—he has not done so up to his time, but he will have to do it. You can put the Diesel engine where an ordinary steam engine would go, and think it will be all right, but oftentimes it will not be, because the vessel is not designed to use the engine, and you have got to make changes in the vessels, and make propellers to suit the Diesel engine, and the conditions generally must be made applicable to the service of the Diesel engine. You must get 85 per cent. efficiency to-day, but that is a thing which is not likely to occur in the case of all kinds of ships. We found with 275 revolutions that we were hopelessly out of it, and expected to be out of it, but did not like to put in transmission gear to reduce the speed, because we wanted to have only one experiment at a time, and intend to experiment with the transmission gear later on. If you are to get the best results out of the full-power operation of the apparatus, then you must cut down in the revolutions, and you cannot do that with the Diesel engine and keep the weight down and keep the economy, and therefore you have got to put in transmission gear. That is inevitable.

Another thing—it is very important, I think, to be ready at any moment to make these fine adjustments, which several gentlemen referred to. You find one of the cylinders is beginning to skip, and you must set that cylinder to rights or you will get into trouble.

One of the gentlemen asked about burning fuel at low speeds. That is the serious problem. The engine does not burn fuel at low speed. It is our experience if you back and fill with the engine, a certain amount of oil is left in the cylinder and it is not burned, and it either carbonizes or goes into the lubricating holes to wrist-pins, etc., and there hardens, and there are quite a few of these troubles which you are faced with, but they can be overcome, and are undoubtedly purely mechanical.

In regard to the character of labor required to look after the engine, that does not seem to be anything out of the way. We took some of the parts to a shop in Montreal, and nearly scared the life out of the machinists there, when they found in one case they had to work to a clearance of $\frac{3}{1000}$ of an inch—they got quite a little bit upset about this—but these are troubles which can easily be overcome, and I am positive the Diesel engine has not only to be reckoned with, but reckoned with right now; I further think a great deal of trouble would be obviated if the Diesel engine builders, in every case, would do just as this gentleman has done—speak frankly about the details, the points where trouble may be expected. It would be very much better if they would let out the information they have about the troubles encountered, and show the people where they occur, and how to cure them.

Mr. Davison (Communicated):—In reply to the questions raised by Mr. Monteagle.

First. The supply of fuel oil. The present production of fuel oil amounts to about 1,500,000,000 gallons per annum. From 30 per cent. to 50 per cent. of the crude oil taken from the wells is available for fuel oil, and except for road making has very little other use. For every gallon of gasoline produced there is about five gallons of fuel oil. The present supply of fuel oil on the eastern coast of the United States is sufficient to have warranted its use to the exclusion of coal on our latest torpedo boat destroyers. It has been stated that the Navy Department proposes to fit the latest Dreadnoughts to burn fuel oil only under their boilers. As a gallon of oil in a Diesel engine will do from three to four times the work that is now being obtained from its use in steam plants, it seems apparent that the supply is sufficient to warrant its use in engines of large power. The writer of this paper does not mean to give the impression that internal combustion engines will entirely displace steam turbines and reciprocating engines.

Second. In regard to using a compression of 500 pounds per square inch. This limit has not been arbitrarily fixed, but has been arrived at as a result of experience. A higher pressure would be objectionable on account of the additional strength of parts required. Too low a pressure is objectionable for the reason that ignition, combustion, and efficiency are interfered with. The lowest pressure successfully used is about 400 pounds.

Third. A piston speed of 1,000 feet per minute is used only on the lighter high speed types of engines, and a number of engines now running do not seem to have met with any serious difficulty. In ordinary heavy type engines the piston speed varies from 600 to 800 feet per minute.

Fourth. The figures for annual cost of repairs for a steam plant were arrived at by consulting the records of certain torpedo boats and destroyers. The figures for the oil engine were estimated based on reports from users of Diesel engines.

In reply to questions raised by Mr. Crane.

While it is true that the Diesel engine has been known for more than fifteen

years, it is only within the past four or five years that any serious attempt has been made to use it for marine purposes. This mere fact, however, does not appear to affect the merits of the engine itself. The engine, with a capacity of 2,000 horse-power per cylinder, was built within the past year in Nuremburg, Bavaria, by the Maschinenfabrik Augsburg-Nürnberg.

It is true that the pressure of 500 pounds per square inch present certain difficulties. These difficulties have fortunately been overcome.

In reply to the question as to where we may look for trouble. A complete answer to this question would be difficult. In general the troubles may be divided into two classes. First, those which are purely mechanical and which would be found in any engine, namely, hot bearings, loose connections, etc. For this class the troubles in a Diesel engine are no more, nor no less, than in a steam engine. The factors of safety used are about the same in both types. Troubles peculiar to Diesel engines are in connection with air compressors, valve springs, auxiliary pumps, etc., which are more than offset by the troubles in a steam plant exterior to the engine itself.

Undoubtedly Diesel engines suffer at the present time due to lack of experience of operatives. This is an evil which will cure itself with time.

In reply to Mr. Robinson.

Flexibility of engine. It has been found in practice that the engines when installed in a ship can be run at one-third the maximum speed. While this paper was being discussed the writer was engaged in the trials of a vessel fitted with Diesel engines. The maximum speed obtained was 380 revolutions per minute. The engine ran smoothly at 150 revolutions per minute, and no effort was made to run at a lower speed. So far as flexibility is concerned, the lowest speeds finally reduce to the question of fly-wheel effect. If for any reason it should be desired to run at a very low speed, with corresponding reduced power, a number of cylinders could be cut out, and the remaining ones used at reduced power. A moderate sized fly-wheel will accomplish this result.

After the engine mentioned had once been warmed up, no trouble was found with ignition at low speeds even when the compression pressure was less than originally designed.

In conclusion, the writer wishes to thank the gentlemen who discussed this paper for the questions raised, and for the additional information furnished.

THE PRESIDENT:—I am sure the thanks of the Society are due to Mr. Davison for his very interesting paper.

We will now take up the paper entitled, "Automatic Record of Propeller Action in an Electrically Propelled Vessel," by Mr. W. L. R. Emmet, Member.

MR. EMMET:—This paper is simply a record taken automatically on an electrically propelled boat, and as the text is short, I will read the paper in full.

The reason for this record being made was that there seemed to be some differences in studying electrical propulsion, as to the need of torque in reversing vessels, and the conditions in this electrically propelled vessel being easy of comprehension, and as the investigation would be of much practical value, I thought it worth while to have some apparatus arranged by which the differences could be studied.

This paper was prepared and the data was got together a comparatively short time before these papers had to be published, and the work of transcribing the records and making up curves from them took a good deal longer than was anticipated, and the paper had to be printed, and I had to send it off without giving very careful study to the records themselves, and while these curves show exactly the conditions observed, it is probable that there are some discrepancies which are not explained in the paper. Mr. Babcock discovered one or two of these discrepancies yesterday, and I talked on the telephone to Schenectady, and I expect to get a partial explanation of what he has called attention to, but I think that these discrepancies have no particular bearing on the purpose of the paper, which is to show the propeller action.

Mr. Babcock has called attention to the fact that on the sheet of general performances the vessel is shown running to a maximum of 10.5 miles, and that in one of the sheets of performance the speed in feet figures up to 11.8 miles.

This discrepancy arises from the fact that an error was made in plotting the first point on the speed curve in question and the speed of the boat on this curve at time of reversal should have been a little over 900 feet a minute instead of 1,100 as marked.

It is probable that there is some error in many of these speeds since the boat was run near the mouth of the Chicago river and the depth of the water varied considerably in different parts of different runs. Shallow water may have easily affected some of the results.

AUTOMATIC RECORD OF PROPELLER ACTION IN AN ELECTRICALLY PROPELLED VESSEL.

By W. L. R. Emmet, Esq., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

In studying the problems connected with electric ship propulsion, the author has encountered some contradictions and differences of opinion concerning the conditions necessary for satisfactory reversal. The discussion of these matters and the lack of definite information which has been discovered has led to the making of the experiments which are here recorded, and although the case is not a representative one, the data being definite and certain have some engineering interest as a basis of comparison.

The fireboat Graeme Stewart is one of two boats owned by the City of Chicago. They are equipped with General Electric turbines which drive centrifugal fire pumps. These turbines are also connected to direct current generators and each of the twin screw propellers is driven by a motor. The fields of these motors are separately energized from a constant potential exciting generator and speed changes are accomplished by changing or reversing the field excitation of the generators.

The automatic record of conditions shown by the accompanying curve sheets was taken by recording ammeters, one of which is shown in the illustration. With this instrument the record of current variations is drawn upon a strip of paper and arrangements are made by which records of equal time intervals and of propeller revolutions are marked upon the same record. In addition to these records, which are easily provided for, a propeller log was rigged on an outrigger near the bow of the boat and connected through an electric circuit in such a manner that a mark was made upon the record strip every time the propeller made a revolution. The log was calibrated by repeated runs over established distances on the Chicago water front and the results of this calibration are shown by the accompanying curve. As this curve indicates, the speed of the vessel through the water can be accurately determined from the marks on the paper down to a speed of about 150 feet per minute.

The accompanying cuts of these automatic records show a rather irregular line for the current record. The current was regulated by the use of the field

rheostat of the generator and a dead beat ammeter in the pilot house, and the average result of the variable currents shown by records is very close to that shown by the curves.

From the records taken directly from these instruments as shown by the curves, other curves have been made showing the variation of speed to power, slip, and average revolutions per minute of the two propellers, and also a curve showing the relation between the torque and the time required to stop the vessel.

In considering the reversal conditions shown by these tests, the propeller characteristics as shown by the slip curve should be borne in mind. The maximum speed which the vessel is capable of making is 11 miles per hour and at this speed the slip is nearly 19 per cent., while at 5 miles per hour it is only 9 per cent. This increase of slip at higher speeds indicates that the propeller is of insufficient size and this deficiency must tend to diminish the value of high torque in reversal.

The apparatus for these tests was arranged by the author's assistant, Mr. Eskil Berg, and the tests were run by him after carefully experimenting with all the parts.

DISCUSSION.

THE PRESIDENT:—Gentlemen, you have heard the paper on "Automatic Record of Propeller Action in an Electrically Propelled Vessel," by Mr. W. L. R. Emmet. The paper is now open for discussion.

PROFESSOR HAROLD A. EVERETT, *Member:*—I would like to ask Mr. Emmet where he located his log with reference to the hull, the length of boom, where the log itself was towed, and the length of the towline.

MR. EMMET:—The log was an outrigger near the bow of the boat, and at about 15 feet from the bow, to one side, so as to clear the bow.

MR. EVERETT:—How long a line?

MR. EMMET:—No line; it was an outrigger.

MR. EVERETT:—So as to clear the waves of the bow?

MR. EMMET:—Yes, entirely.

MR. EVERETT:—In that case I would like merely to call attention to the calibration curve. It is quite an interesting curve, for the reason that the part that deals with half speed and lower occupies about 96 per cent. of the plate. Of course, in general, the part of the speed curve that is of interest is from half-speed up. From this plate, if we assume that the points lie exactly on the curve, the width of line of the curve itself permits an inaccuracy of about 3 per cent., in the determination of speed, and further if one admits a deviation of the points from the curve, as they seem to have, of very slight amounts, possibly half of one of the coordinate spaces, that would correspond to an inaccuracy of five per cent. on speed. This would be roughly about 16 per cent. on power, assuming that the power is proportional to the cube of the speed, and I would question the statement made by Mr. Emmet in the early part of the paper where he says: "As this curve indicates, the speed of the vessel through the water can be accurately determined from the marks on the paper down to a speed of about 150 feet per minute."

THE PRESIDENT:—Is there any further discussion? Mr. Emmet, have you anything to say in reply?

MR. EMMET:—I have not quite followed that last criticism. My meaning in stating that the speed can be determined down to 150 feet per minute had no reference particularly to the scale of this curve. It had reference to the speed at which this curve bends. As long as the curve keeps reasonably straight, the action of the log is reasonable in proportion, but the characteristic of its action is unstable. However, when the log begins to slip, then we could not trust it, and while the curve may be drawn to a bad scale, we should not regard it at all, because the regular speed is by dots which are spaced on a moving paper, and the spacing of these dots has a very definite regard for the number of holes of the log. If you note the general characteristic of the log with relation to its motion in the water, we can determine the speed with accuracy.

THE PRESIDENT:—If there is no further discussion, we will pass to the next paper, after recording the thanks of the Society to Mr. Emmet for his paper.

The next two papers will be the last papers of this meeting. The authors are not present, and they will be read by title, in order to afford an opportunity for such discussion as may be offered.

The first paper to be presented is entitled, "Ship Calculations; Derivation and Analysis of Methods," by Naval Constructor T. G. Roberts, Member.

SHIP CALCULATIONS; DERIVATION AND ANALYSIS OF METHODS.

By Naval Constructor T. G. Roberts, U. S. N., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

In presenting a paper dealing with the first elements of a subject so well known to naval architects, reliance is placed mainly upon the possibility of interesting those who may find in these notes a shorter or clearer method of teaching the subject comprehensively to the student, aside from the desire to put into the proceedings a presentation of the entire subject along the same general lines as practiced by the French, as nearly as my recollection permits. The formulæ used were pieced together by the writer several years ago while preparing for an examination for promotion, and the practical examples worked out at that time are herein included to make clearer the application of the formulæ. If this paper may serve to alleviate the efforts of some student searching diligently for the reasons why, which were not always clear to the writer, in the calculation tables, until he had dug out these formulæ for himself, I shall then feel justified in having prepared the paper.

It is to be hoped the reader will not become discouraged at the displacement and incidental calculations at the start, as the subsequent matter is less complicated and more interesting.

DISPLACEMENT.

The symbols are used to indicate the following:

A = Water-line areas.
S = Areas of sections.
w = Vertical interval between adjacent water-lines.
s = Horizontal interval between adjacent sections.
V = Volume of displacement.
D = Displacement in salt water.
D' = Displacement in fresh water.
T = Displacement in tons per inch of immersion.
y = Ordinates of water-lines and sections.

The volume of displacement may be obtained by summing up either the curve of water-line areas or the curve of sectional areas; thus

$$V = \int A dz = \int S dx \qquad (1)$$

where dz and dx are the vertical and horizontal intervals, respectively.

Integrating the above we have

$$V = w\Sigma A = s\Sigma S. \tag{2}$$

In (2) Σ is the sign of summation either by the trapezoidal rule, or Simpson's rule, or any other rule. The trapezoidal rule is used by the French and United States governments, and Simpson's rule by the British.

In practice V is not usually determined from the equations in (2) but directly from the ordinates. To decompose (1) into terms of its ordinates,

$$A = 2\int ydx$$

and

$$S = 2\int ydz$$

where y differs in the two, being summed in the first instance along the water-line area, and in the second, down the sectional area. These equivalents thus give us a valuable check on each other in practice. Substituting either the value of A or of S in (1) we get the same value for V, thus

$$V = 2\int\int ydxdz. \tag{3}$$

If now we integrate, by summation, for stations dx, a fixed distance, s apart; and for dz a distance w apart, we have the practical form, since s and w are constants

$$V = 2\ sw\Sigma\Sigma y. \tag{4}$$

Although Σ is the sign of summation by Simpson's rule, or other rule, the author prefers the trapezoidal method of summing areas, and in this paper it will be taken to represent the trapezoidal sum, which means that

$$\Sigma y = \tfrac{1}{2}y_1 + y_2 + y_3 \ . \ . \ . \ . \ y_{n-1} + \tfrac{1}{2}y_n \tag{5}$$

and

$$\Sigma\Sigma y = \tfrac{1}{2}\Sigma y_1 + \Sigma y_2 + \Sigma y_3 \ . \ . \ . \ . \ \Sigma y_{n-1} + \tfrac{1}{2}\Sigma y_n \tag{6}$$

That is to say $\Sigma\Sigma$ represents the trapezoidal sum of the trapezoidal sum of the ordinates, and as derived in (3) may be summed either way, by sections or water-lines.

Table I gives a practical example showing the method of calculating the value $\Sigma\Sigma y$ preliminary to determining the value of V in (4); the ordi-

nates of a United States Government tug are used in the calculations, and the method itself is identical with that used by the French government. The signs Σ and $\Sigma\Sigma$ are placed at the side and bottom of the columns so the reader can easily follow the operations. I may remark here that the trapezoidal method of summation is far more versatile and extensive in its application than Simpson's rules, but depends for its accuracy upon a careful correction of the end ordinates. It is taken for granted the reader will correct the end ordinates before putting the figures into the formulæ. It is also to be pointed out in particular that in formula (6) the first and last terms involve the values

$$\tfrac{1}{2}\Sigma_1 \text{ and } \tfrac{1}{2}\Sigma_n.$$

Therefore note that

$$\tfrac{1}{2}\Sigma y = \tfrac{1}{4}y_1 + \tfrac{1}{2}y_2 \; . \; . \; . \; . \; \tfrac{1}{2}y_{n-1} + \tfrac{1}{4}y_n.$$

For easy reference the figures ($\frac{1}{4}$) are put at the four corners of the table, and ($\frac{1}{2}$) at the four sides, to indicate that portion of the end ordinates to be entered into the columns.

We may now assemble together the working formulæ:

$$S = 2w\Sigma y \qquad \text{(a)}$$

$$A = 2s\Sigma y \qquad \text{(b)}$$

$$V = 2sw\Sigma\Sigma y \qquad \text{(c)}$$

$$D = \frac{V}{35} \qquad \text{(d)}$$

$$T = \frac{A}{420} \qquad \text{(e)}$$

Tables I, II and III are used to calculate these results and the three tables are here given separately to show the method of derivation, and for the sake of simplicity of explanation, but may be combined, for operation, into a single form.

Table I gives the Σ functions of water-line areas by summing horizontally, and the Σ functions of sectional areas by summing vertically; the summation of these functions, separately, in the lowest line, or the right column, gives a check on the value of the $\Sigma\Sigma$ function of the displacement. The most noteworthy thing about this table is its simplicity due to the small size and number of figures used.

The Subtractive Method.—In Table I we have found $\Sigma\Sigma_5$, which is the function of the volume of displacement to the fifth, which is the upper,

water-line. It remains for us to find the similar functions of the fourth, third, second, and first water-lines from $\Sigma\Sigma_5$.

TABLE I.—TO FIND FUNCTIONS OF AREAS OF WATER-LINES AND SECTIONS, AND OF DISPLACEMENT, FROM THE ORDINATES; OR, GIVEN THE VALUES OF y, TO FIND Σ, AND $\Sigma\Sigma_5$.

Numbers of sections.	Numbers of water-lines.					Functions of sections to fifth water-line.	
	5	4	3	2	1		
0	$(\frac{1}{4})$ 0.1	$(\frac{1}{2})$ 0.1	$(\frac{1}{2})$ 0.1	$(\frac{1}{2})$ 0.0	$(\frac{1}{4})$ 0.0	0.3	$(\frac{1}{2})\ \Sigma_0$
1	$(\frac{1}{2})$ 1.7	2.8	2.0	1.1	$(\frac{1}{2})$ 0.1	7.7	Σ_1
2	$(\frac{1}{2})$ 3.4	6.1	5.0	3.5	$(\frac{1}{2})$ 0.6	18.6	Σ_2
3	$(\frac{1}{2})$ 4.5	8.6	7.7	6.1	$(\frac{1}{2})$ 1.5	28.4	Σ_3
4	$(\frac{1}{2})$ 5.1	9.9	8.3	7.9	$(\frac{1}{2})$ 2.1	33.3	Σ_4
5	$(\frac{1}{2})$ 5.2	10.4	10.0	8.6	$(\frac{1}{2})$ 2.4	36.6	Σ_5
6	$(\frac{1}{2})$ 5.2	10.4	10.1	8.7	$(\frac{1}{2})$ 2.5	36.9	Σ_6
7	$(\frac{1}{2})$ 5.1	10.1	9.6	7.9	$(\frac{1}{2})$ 2.1	34.8	Σ_7
8	$(\frac{1}{2})$ 4.9	9.3	8.2	5.5	$(\frac{1}{2})$ 1.2	29.1	Σ_8
9	$(\frac{1}{2})$ 4.1	7.1	4.7	2.3	$(\frac{1}{2})$ 0.4	18.6	Σ_9
10	$(\frac{1}{4})$ 1.8	$(\frac{1}{2})$	$(\frac{1}{2})$	$(\frac{1}{2})$	$(\frac{1}{4})$	1.8	$(\frac{1}{2})\ \Sigma_{10}$
Functions of of areas of water-lines.	41.1	74.8	65.7	51.6	12.9	246.1	$\Sigma\Sigma_{10}$
	$(\frac{1}{2})\ \Sigma_5$	Σ_4	Σ_3	Σ_2	$(\frac{1}{2})\ \Sigma_1$	$\Sigma\Sigma_5$	Check.

Likewise, in column 7, we have found the functions of sectional areas up to the highest, or fifth water-line, and we may desire to know these functions to each water-line; and must subtract the half sum of the two upper ordinates to get the function of the sectional area to the next lower line.

We have

$$\Sigma_5 = \tfrac{1}{2}y_1 + y_2 + y_3 + y_4 + \tfrac{1}{2}y_5.$$

To get from this the similar function to the fourth water-line, we must subtract $\frac{y_4 + y_5}{2}$ or one-half the two upper ordinates; thus

$$\Sigma_4 = \Sigma_5 - \frac{y_4 + y_5}{2} = \tfrac{1}{2}y_1 + y_2 + y_3 + \tfrac{1}{2}y_4$$

and so on, for the functions of the lower water-lines.

That is, to get from any water-line to the next lower water-line, we must subtract the half sums of the upper ordinates in each case. If these subtractions be made, it will be the equivalent of removing the slice of the underwater body of the ship between the fifth and fourth water-planes; and the sum of the results, after these subtractions, will be $\Sigma\Sigma_4$, the function of the volume of displacement up to the fourth water-line. If we apply the same method to $\Sigma\Sigma_4$, $\Sigma\Sigma_3$ may be found, and so on to the lowest water-line.

It is necessary to apply these end subtractions back to the ordinates when we have to subtract moments as well as volumes; and this subtractive method is subject to be applied throughout all the ship calculations where applicable. For the purposes of this paper, however, we will avoid the question of moments, and consider merely the calculations for volume of displacement. In that case, we do not need to use the ordinates, but may find $\Sigma\Sigma_4$ directly from $\Sigma\Sigma_5$; thus

$$\Sigma\Sigma_4 = \Sigma\Sigma_5 - \frac{\Sigma_5 + \Sigma_4}{2} = \tfrac{1}{2}\Sigma_1 + \Sigma_2 + \Sigma_3 + \tfrac{1}{2}\Sigma_4$$

and so on for the functions of volumes of displacement to the other water-lines.

TABLE II.—HAVING THE FUNCTIONS OF V_5 FROM TABLE I, TO FIND FUNCTIONS OF V_4, V_3, V_2, V_1. THAT IS, FROM $\Sigma\Sigma_5$ FIND $\Sigma\Sigma_4$, $\Sigma\Sigma_3$, $\Sigma\Sigma_2$, AND $\Sigma\Sigma_1$.

Last line. Table I.	Subtract from column 1.	Function of V_4.	Subtract from column 3.	Function of V_3.	Subtract from column 5.	Function of V_2.	Subtract from column 7.	Function of V_1.
1	2	3	4	5	6	7	8	9
$\Sigma\Sigma_5$	$\frac{\Sigma_5+\Sigma_4}{2}$	$\Sigma\Sigma_4$	$\frac{\Sigma_4+\Sigma_3}{2}$	$\Sigma\Sigma_3$	$\frac{\Sigma_3+\Sigma_2}{2}$	$\Sigma\Sigma_2$	$\frac{\Sigma_2+\Sigma_1}{2}$	$\Sigma\Sigma_1$
246.1	78.5	167.6	70.25	97.35	58.65	38.70	38.70	0.00

If we should desire to know Σ_5, Σ_4, Σ_3, Σ_2, and Σ_1, which are the functions of sectional areas up to the fifth, fourth, third, etc., water-lines, we can take the values of Σ_5 from column 7 of Table I, arrange them in column similar to Table II, and obtain the functions Σ_4, etc., by subtracting successively the half sums of the upper ordinates each time. This is mentioned because the areas of sections to each water-line are found in the American calculations. In the French method, only the areas of sections to the highest, or the load water-line are found, being sufficient for the purpose of design.

We are now prepared to assemble in Table III, the results found by applying the formulæ to the quantities found in the Tables I and II. The areas of sections to the fifth water-line are found and the columns contain the signs which indicate all the operations performed.

TABLE III.—TO FIND S, A, V, D, AND T FROM TABLES I AND II: $w = 2$ feet; $s = 9.17$ feet.

Functions of sections to fifth water-line Table I.		S sq. ft. / $2w\Sigma_y$	Functions of water-line areas, Table I.		A sq. ft. / $2s\Sigma_y$	Values of $\Sigma\Sigma_y$ from Table II.		V cu. ft. / $2sw\Sigma\Sigma_y$	D tons $\frac{V}{35}$	D' fresh water $=0.9722D$	T tons per inch $\frac{A}{420}$
1	2	3	4	5	6	7	8	9	10	11	12
$(\frac{1}{2})\ \Sigma_0$	0.3	2.4	$(\frac{1}{2})\ \Sigma_5$	41.1	1,507.5	$\Sigma\Sigma_5$	246.1	9027	257.9	250.7	3.6
Σ_1	7.7	30.8	Σ_4	74.8	1,371.8	$\Sigma\Sigma_4$	167.6	6148	175.6	170.7	3.3
Σ_2	18.6	74.4	Σ_3	65.7	1,204.9	$\Sigma\Sigma_3$	97.35	3571	102.6	99.2	2.9
Σ_3	28.4	113.6	Σ_2	51.6	946.3	$\Sigma\Sigma_2$	38.70	1420	40.6	39.5	2.2
Σ_4	33.3	133.2	$(\frac{1}{2})\ \Sigma_1$	12.9	473.2	$\Sigma\Sigma_1$	0.00	0	0.0	0.0	1.1
Σ_5	36.6	146.4	—	—	—	—	—	—	—	—	—
Σ_6	36.9	147.6	—	—	—	—	—	—	—	—	—
Σ_7	34.8	139.2	—	—	—	—	—	—	—	—	—
Σ_8	29.1	116.4	—	—	—	—	—	—	—	—	—
Σ_9	18.6	74.4	—	—	—	—	—	—	—	—	—
$(\frac{1}{2})\ \Sigma_{10}$	1.8	14.4	—	—	—	—	—	—	—	—	—

The Additive Method.—Instead of finding first the volume at the upper water-line and working downward, it is the custom in the United States method to commence at the lower water-line, and work upward in successive functions, which is just the reverse of the subtractive method. Thus, the functions of the areas of sections to the lowest water-line is found first, and then the function of that to the next higher water-line is found by adding the half sum of the upper ordinates, and so on. Thus, having found

$$\Sigma_4 = \tfrac{1}{2}y_1 + y_2 + y_3 + \tfrac{1}{2}y_4$$

we have

$$\Sigma_5 = \Sigma_4 + \frac{y_4 + y_5}{2}$$

Likewise, having found

$$\Sigma\Sigma_1,$$

we have

$$\Sigma\Sigma_2 = \Sigma\Sigma_1 + \frac{\Sigma_1 + \Sigma_2}{2}$$

and so on.

Tables IV and V give the additive method of calculating the same quantities as previously found by the subtractive method, using the same ordinates and obtaining the same results. (See pp. 266 and 267).

The latter method has been explained first because of its simplicity, and it leads to a quicker understanding of the additive method.

In Table IV, the numbers of sections are placed in the left hand column, and the numbers of water-lines in the upper line as before, except that the lowest water-line is placed first, on the left side, since we work from the first water-line, upward, and not from the fifth downward as in Table I; so the order of the water-lines is reversed in the two methods.

We also include the additional columns, with even numbers, 4, 6, 8, etc., in which to sum the ordinates as we proceed.

In the subtractive method it is easy to subtract the half sums of top ordinates, but in the additive method it is more complicated, and the half sums would have to be worked out separately on a different piece of paper. To obviate this, twice the trapezoidal sums of ordinates is found by adding successively the sum of the upper two ordinates. Thus

$$2\Sigma_4 = y_1 + 2y_2 + 2y_3 + y_4,$$
$$2\Sigma_5 = 2\Sigma_4 + (y_4 + y_5).$$

This facilitates the additions of ordinates, and the double function 2Σ can be used directly in the formula $S = w(2\Sigma_y)$.

The same method is employed to get volumes, for similar reasons, and instead of finding $\Sigma\Sigma_1$, $\Sigma\Sigma_2$, etc., as before, we find $2\Sigma\Sigma_1$, $2\Sigma\Sigma_2$, or double the functions of volumes, which can be used directly in the formula $V = sw(2\Sigma\Sigma)$. For this reason it is not necessary to enter the one-fourth and one-half ordinates, as in Table I, but we must enter the whole ordinates in each odd-numbered column. From the sums of these columns we subtract one-half the sums of end ordinates to get Σ_1, Σ_2, etc., for the water-lines.

From these values we build up the values of $2\Sigma\Sigma$ thus

$$2\Sigma\Sigma_1 = \Sigma_1$$
$$2\Sigma\Sigma_2 = \Sigma_1 + \Sigma_2$$
$$2\Sigma\Sigma_3 = \Sigma_1 + 2\Sigma_2 + \Sigma_3$$
$$2\Sigma\Sigma_4 = \Sigma_1 + 2\Sigma_2 + 2\Sigma_3 + \Sigma_4, \text{ etc.}$$

TABLE IV.—TO CALCULATE WATER-LINE AREAS, TONS PER INCH, SALT AND FRESH WATER DISPLACEMENT FROM THE ORDINATES.

	Nos. of sections.	Water-lines.											
		1 Ordinates y_1.	$2\Sigma_1 = y_1$ Sum column 3. Functions for areas of sections to first water-line.	2 Ordinates y_2.	$2\Sigma_2 = y_1 + y_2$ Sum columns 4 and 5. Functions of S to second water-line.	3 Ordinates y_3.	$2\Sigma_3 = y_1 + 2y_2 + y_3$ Sum columns 5, 6 and 7. Functions of S to third water-line.	4 Ordinates y_4.	$2\Sigma_4 = y_1 + \text{etc.}$ Sum columns 7, 8 and 9. Functions of S to fourth water-line.	5 Ordinates y_5.	$2\Sigma_5 = y_1 + \text{etc.}$ Sum columns 9, 10 and 11. Functions of S to fifth water-line.	$2\Sigma y_5$ Functions of S to last water-line taken.	
$A = 2s\Sigma_y$. $D = \frac{V}{35} = \frac{2sw\Sigma\Sigma_y}{35}$. $D' = 0.9722D$. $T = \frac{A}{420}$	2	3	4	5	6	7	8	9	10	11	12	13	14
	0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.6	0.4	1.2	1.2	$2\Sigma_0$
	1	0.2	0.2	1.1	1.3	2.0	4.4	2.8	9.2	3.4	15.4	15.4	$2\Sigma_1$
	2	1.2	1.2	3.5	4.7	5.0	13.2	6.1	24.3	6.8	37.2	37.2	$2\Sigma_2$
	3	3.0	3.0	6.1	9.1	7.7	22.9	8.6	39.2	9.0	56.8	56.8	$2\Sigma_3$
	4	4.2	4.2	7.9	12.1	8.3	28.3	9.9	46.5	10.2	66.6	66.6	$2\Sigma_4$
	5	4.8	4.8	8.6	13.4	10.0	32.0	10.4	52.4	10.4	73.2	73.2	$2\Sigma_5$
	6	5.0	5.0	8.7	13.7	10.1	32.5	10.4	53.0	10.4	73.8	73.8	$2\Sigma_6$
	7	4.2	4.2	7.9	12.1	9.6	29.6	10.1	49.3	10.2	69.6	69.6	$2\Sigma_7$
	8	2.4	2.4	5.5	7.9	8.2	21.6	9.3	39.1	9.8	58.2	58.2	$2\Sigma_8$
	9	0.8	.8	2.3	3.1	4.7	10.1	7.1	21.9	8.2	37.2	37.2	$2\Sigma_9$
	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	7.2	7.2	$2\Sigma_{10}$
1 Sums of odd number columns.....			25.8		51.6		65.8		74.9		86.0	496.4	—
2 Half sums end ordinate to deduct..			0.0		.0		0.1		0.1		3.8	4.2	—
3 Functions of water-line areas.....			$\Sigma_1 =$ 25.8		$\Sigma_2 =$ 51.6		$\Sigma_3 =$ 65.7		$\Sigma_4 =$ 74.8		$\Sigma_5 =$ 82.2	=492.2	$2\Sigma\Sigma_{10}$
4 Functions of displacement to W. L.			$2\Sigma\Sigma =$ 25.8		$2\Sigma\Sigma_2 =$ 77.4		$2\Sigma\Sigma_3 =$ 194.7		$2\Sigma\Sigma_4 =$ 335.2		$2\Sigma\Sigma_5 =$ 492.2	Check.	—
5 Water-line areas (Line $3 \times 2s$).....			473.2		946.3		1204.9		1371.8		1507.5	—	—
6 Tons per inch $\frac{A}{420}$.....			1.1		2.2		2.9		3.3		3.6	—	—
7 Displ. $= \frac{sw}{35}(2\Sigma\Sigma) =$ Line $4 \times \frac{sw}{35}$..			0.0		40.6		102.0		175.6		257.9	—	—
8 D' = Displacement F. W. $= 0.9722D$			0.0		39.5		99.2		170.7		250.7	—	—

All the additional explanations needed are given in the columns of Table IV, and the signs have been added to indicate the values therein contained. Table V is taken directly from Table IV, and the even numbered columns of Table IV are multiplied by w for the values of S.

TABLE V.—AREAS OF SECTIONS AND VOLUMES OF DISPLACEMENT FROM TABLE IV.

	Numbers of sections.	Numbers of water-lines.			
		Areas of sections.	Areas of sections.	Areas of sections.	Areas of sections.
		Column 6, Table IV. $\times w$.	Column 8, Table IV. $\times w$.	Column 10, Table IV. $\times w$.	Column 12, Table IV. $\times w$.
	1	2	3	4	5
$S = 2w\Sigma y$. $V = s\Sigma S$. $w = 2$ feet. $s = 9.17$ feet.	0	(½) 0.0	(½) 0.2	(½) 0.6	(½) 1.2
	1	2.6	8.8	18.4	30.8
	2	9.4	26.4	48.6	74.4
	3	18.2	45.8	78.4	113.6
	4	24.2	56.6	93.0	133.2
	5	26.8	64.0	104.8	146.4
	6	27.4	65.0	106.0	147.6
	7	24.2	59.2	98.6	139.2
	8	15.8	43.2	78.2	116.4
	9	6.2	20.2	43.8	74.4
	10	(½) 0.0	(½) 0.0	(½) 0.0	(½) 7.2
1. Sums of columns.....	—	154.8	389.4	670.4	984.4
2. Volumes in cubic feet to each water-line.....	—	1420	3571	6148	9027
3. Line 1 $\times s$.....	—	V_2	V_3	V_4	V_5

We are now in position to compare the subtractive with the additive method. The latter, as we have seen, requires a far greater number of additions, extending over three columns as in Table IV, and the sources of error are thus increased. Furthermore, the large figures handled in the even columns of the same table, due to the summing of the double functions, 2Σ, furnish an additional source of error in adding, to say nothing of the

time it requires. In short the subtractive method is much simpler, is less liable to error, and requires much less time to work out. The additive method, however, combines more calculations on one sheet of paper. The subtractive method has another great advantage in brevity. By it we find, directly, the various functions to the upper water-lines, which may be extended to include the determination not only of the displacement, but also of metacenters, moments of stability, changes of trim, and in fact the whole ground of ship calculations. This upper water-line is the extreme upper limit to which calculations are carried, and in a ship of size and importance, from twelve to fourteen water-lines are used, the tenth being always the load water-line. It is only in a few smaller vessels, like the tug calculated in Tables I to V, that a fewer number of water-lines than ten are used. Take, for instance, a ship divided into twelve water-lines for the calculations; the values of displacement and stability functions are found for the twelfth water-line, at once, as in Table I. Now, by the subtractive method, the functions for the eleventh, tenth, ninth, eighth, seventh and sixth water-lines are found but no more, since the vessel will never float at a draft less than that of the sixth water-line, nor even as small; and so it is considered a loss of time to find these functions for the lower water-lines. In the additive method, we commence at the first water-line, and include every one up to the twelfth, which not only requires the additional time and labor, but if an error is made in one of the lower water-lines, it is carried on to the upper water-line, and is more difficult to discover and correct. Preference is to be given to the subtractive method, for by it the simplicity and beauties of the trapezoidal rule are utilized to full advantage.

Displacement Calculations by Simpson's Rules.—The first rule is almost exclusively used, and its application to the formulæ is precisely the same as in the trapezoidal rule except that the signs Σ_y and $\Sigma\Sigma_y$ have a different meaning.

If Simpson's rule be used

$$\Sigma_y = \tfrac{1}{3}(y_1 + 4y_2 + 2y_3 + 4y_4, \text{ etc.})$$

and

$$\Sigma\Sigma_y = \tfrac{1}{3}(\Sigma_1 + 4\Sigma_2 + 2\Sigma_3 + 4\Sigma_4, \text{ etc.})$$

We can form tables dealing with the ordinates, by this rule, but we must include the multipliers, 1, 4, 2, 4, etc., for both ordinates and Σ's, which complicates the calculations and increases the size of the figures handled. With this modification, Simpson's rule can be applied to all the foregoing formulæ, where Σ and $\Sigma\Sigma$ are used; and in fact these formulæ

govern every operation applied to Simpson's rules, the same as the trapezoidal rule. It is evident that even the additive method with the trapezoidal rule, is far simpler than the Simpson rule, and requires much less time.

CENTER OF GRAVITY OF CURVILINEAR FIGURE AND WATER-LINE.

1. *Longitudinally.*—Taking the origin at the lower left hand corner, the area of a vertical element of summation is expressed by ydx, and its moment about the origin by $xydx$. Summing for the entire area the moment, $M = \int xydx$ and the area, $A = \int ydx$. If $\underline{x}$ = the distance of the center of gravity from the origin then

$$\underline{x} = \frac{M}{A} = \frac{\int xydx}{\int ydx} \tag{1}$$

Transpose this into the working formulæ, and we have

$$\underline{x} = \frac{s\Sigma xy}{s\Sigma y} \tag{2}$$

In developing the values of xy in the numerator, x is equal to 0, s, $2s$, $3s$, $4s$, etc., for the various values y_0, y_1, y_2, y_3, y_4, etc., of the ordinates, assuming the vertical axis through the origin to coincide with y_0; therefore for any ordinate, y_n, we may place $x = ns$; and put s, the constant, outside the sign leaving n inside, where n is the number of intervals y is distant from the origin. Thus

$$\underline{x} = \frac{s^2\Sigma ny}{s\Sigma y} = \frac{s\Sigma ny}{\Sigma y} \tag{3}$$

To find the center of gravity of a water-line, it is evident that equation (3) holds good, for although the moments are doubled for the two sides, the area is likewise doubled, and the common factor cancels out. Thus

$$\underline{x} = \frac{2\int xydx}{2\int ydx} = \frac{2s^2\Sigma ny}{2s\Sigma y} = \frac{s\Sigma ny}{\Sigma y} \tag{4}$$

This gives two equations which we will consider separately.

$$\underline{x} = \frac{2s^2\Sigma ny}{A} \tag{5}$$

where A = area of water-line.

Equation (5) is used altogether in making actual ship calculations for the reason that A is already known from Table IV, areas being always calculated before moments; so we have to find only the numerator to determine $\underline{x}$.

If, however, we have to find the center of gravity of a water-line as a separate problem, the following is preferred, being simpler

$$x = \frac{s\Sigma ny}{\Sigma y} \tag{6}$$

Example.—The corrected semi-ordinates of the load water-plane of a vessel 368 feet long, commencing aft, are 9.2, 22.3, 29.5, 33.6, 35.7, 36.1, 34.5, 29.2, 21.2, 11.5, 1.0 feet respectively. Find the distance of center of gravity from the middle ordinate.

TABLE VI.—TO FIND THE DISTANCE OF THE CENTER OF GRAVITY OF THE LOAD WATER-LINE FROM THE MIDDLE SECTION.

Number of ordinate from forward.	Lengths of ordinates.	Number of intervals from middle ordinate.	Product for moments.
	y	n	ny
1	(½) 0.5	5	2.5
2	11.5	4	46.0
3	21.2	3	63.6
4	29.2	2	58.4
5	34.5	1	34.5
6	36.1	0	205.0
7	35.7	1	35.7
8	33.6	2	67.2
9	29.5	3	88.5
10	22.3	4	89.2
11	(½) 4.6	5	23.0
$\Sigma y = 258.7$			−303.0
		$\Sigma ny = -98.6$	

$$s = 36.8$$

$$s\Sigma ny = -98.6 \times 36.8$$

$$\underline{x} = \frac{s\Sigma ny}{\Sigma y} = \frac{-98.6 \times 36.8}{258.7} = -14.03 \text{ ft.}$$

2. *Transversely, as for Half Water-line.*—Starting with the conventional ydx as the vertical generating strip of the area, its moment about the x axis is equal to:

$$ydx \times \tfrac{1}{2}y = \tfrac{1}{2}y^2dx;$$

the moment for the entire area, $M = \frac{1}{2}\int y^2dx$.

Taking y as the distance of the center of gravity from the x axis, then

$$\underline{y} = \frac{M}{A} = \frac{\frac{1}{2}\int y^2dx}{\int ydx} = \frac{1}{2}\frac{s\Sigma y^2}{s\Sigma y}$$

Or, taking the working formula, we have

$$\underline{y} = \frac{\Sigma y^2}{2\Sigma y} \tag{1}$$

In using this formula it must be noted in particular that

$$\Sigma y^2 = \tfrac{1}{2}y_1^2 + y_2^2 + y_3^2 \ldots y^2_{n-1} + \tfrac{1}{2}y_n^2 \tag{2}$$

CENTER OF BUOYANCY.

1. *Longitudinally.*—The longitudinal position of the center of buoyancy of a vessel is obtained by taking the algebraic sum of the moments of the elementary volumes, Sdx, about the midship section and dividing by the volume. Thus

$$\underline{x} = \frac{M}{V} = \frac{\int Sdx.x}{\int Sdx} = \frac{s\Sigma Sx}{s\Sigma S} \tag{1}$$

Thus x, the distance from S to midship section, equals 0, s, $2s$, $3s$, etc., for the different sections measuring from the midship section toward either end of the ship; thus for a section 8 intervals away $x = 8s$, etc. Put $x = ns$ where n represents the number of intervals, then (1) becomes

$$\underline{x} = \frac{s\Sigma nsS}{s\Sigma S};$$

but s inside the sign is constant, so we may take it outside the sign, and put

$$\underline{x} = \frac{s^2\Sigma nS}{s\Sigma S} = \frac{s\Sigma nS}{\Sigma S}. \tag{2}$$

This gives us the value of x in terms of the sectional areas.

If, however, as is usually the case in ship calculations, we have already found the value of V, we have from (2)

$$\underline{x} = \frac{s^2 \Sigma n S}{V} \tag{3}$$

It is in this form that it is used in standard ship calculations, for we will have already found V, as in Table III or V.

Equation (2) is the simplest form if the values of S are known.

Suppose that we have only the values of the ordinates and desire to find $\underline{x}$ directly from them by the shortest method; we have from (2)

$$\underline{x} = \frac{s \Sigma n S}{\Sigma S}.$$

But $S = 2w\Sigma y$ as found in a previous example.

Therefore

$$\underline{x} = \frac{s \Sigma n (w \Sigma y)}{\Sigma (w \Sigma y)};$$

w is constant, therefore we place it outside the sign, and cancel it from numerator and denominator.

Thus

$$\underline{x} = \frac{s \Sigma (n \Sigma y)}{\Sigma \Sigma y} \tag{4}$$

which gives the result directly from the ordinates.

Either (2), (3), (4), or (5), may be used to obtain the same results, and let us assemble them in proper form as follows:

$$\underline{x} = \frac{s \Sigma n S}{\Sigma S} \quad \text{from sectional areas.} \tag{2}$$

$$\underline{x} = \frac{s^2 \Sigma n S}{V} \quad \text{from sectional areas and volume.} \tag{3}$$

$$\underline{x} = \frac{s \Sigma (n \Sigma y)}{\Sigma \Sigma y} \quad \text{directly from the ordinates.} \tag{4}$$

or

$$\underline{x} = \frac{2 s^2 w \Sigma (n \Sigma y)}{V} \quad \text{from ordinates and volume.} \tag{5}$$

(5) is evident from (4) since $V = 2sw\Sigma\Sigma y$.

In any given problem, if we have the ordinates, they are treated as in Table I for the values of Σy, and from them the value of $\underline{x}$ is found as above.

If, however, we prepare combination tables in which are included the usual ship calculations, we may use any one of the above formulæ so as to fit to the forms most conveniently.

TABLE VII.—LONGITUDINAL POSITION OF CENTER OF BUOYANCY BY FOUR METHODS. STEAM TUG OF TABLES I TO V.

Number of stations.	Σy from Table III, column 2.	n	$n\Sigma y$	S from Table III, column 3.	nS
1	(½) 0.3	5	(½) 1.5	(½) 1.2	(½) 6.0
2	7.7	4	30.8	30.8	123.2
3	18.6	3	55.8	74.4	223.2
4	28.4	2	56.8	113.6	227.2
5	33.3	1	33.3	133.2	133.2
6	36.6	0	178.2	146.4	712.8
7	36.9	1	36.9	147.6	147.6
8	34.8	2	69.6	139.2	278.4
9	29.1	3	87.3	116.4	349.2
10	18.6	4	74.4	74.4	297.6
11	(½) 1.8	5	(½) 9.0	(½) 7.2	(½) 36.0
$\Sigma\Sigma y = 246.1$		$\Sigma(n\Sigma y)$	-277.2 -99.0	984.4 ΣS	-1108.8 $\Sigma nS = -396.0$
$s = 9.17$ feet $V_5 = 9027$ cubic feet. from Table III.		$\frac{s\Sigma(n\Sigma y)}{\Sigma\Sigma y} = \frac{99.0 \times 9.17}{246.1}$ $\underline{x} = -3.69$ $\frac{2s^2w\Sigma(n\Sigma y)}{V} = \frac{-99 \times (9.17)^2 \times 4}{9027}$ $\underline{x} = -3.69$		$\frac{s\Sigma nS}{\Sigma S} = \frac{-396 \times 9.17}{984.4}$ $\underline{x} = -3.69$ $\frac{s^2\Sigma ns}{V} = \frac{-396 \times (9.17)^2}{9027}$ $\underline{x} = -3.69$	

The foregoing example finds the value of $\underline{x}$ for V_5 only, and if its value for a lower water-line is desired, we have but to add or subtract the half sums of end ordinates successively in reducing to the next water-line below.

2. *Vertically.*—We use the symbol $\underline{z}$ to denote its distance below the load water-line. The volume being generated by a water-line area A moved in the direction z, an element of volume is Adz; and this multiplied by its distance z, gives its moment about the load water-line. The sum

of the moments of all the elementary volumes, divided by the whole volume will give $\underline{z}$. Thus

$$\underline{z} = \frac{M}{V} = \frac{\int A dz.z}{\int A dz} = \frac{w^2 \Sigma n A}{w \Sigma A} = \frac{2sw^2 \Sigma(n \Sigma y)}{2sw \Sigma \Sigma y} = \frac{2sw^2 \Sigma(n \Sigma y)}{V} = \frac{w \Sigma(n \Sigma y)}{\Sigma \Sigma y} \quad (1)$$

all of which are derived precisely as for $\underline{x}$ in the foregoing problem; and, as in that case, we have several expressions of this value, either of which can be used as best suits the problem in hand. Thus

$$\underline{z} = \frac{w \Sigma n A}{\Sigma A} \quad \text{from water-line areas.} \quad (2)$$

$$\underline{z} = \frac{w^2 \Sigma n A}{V} \quad \text{from water-line areas and volume.} \quad (3)$$

$$\underline{z} = \frac{2sw^2 \Sigma(n \Sigma y)}{V} \quad \text{from ordinates and volume.} \quad (4)$$

or

$$\underline{z} = \frac{w \Sigma(n \Sigma y)}{\Sigma \Sigma y} \quad \text{directly from the ordinates.} \quad (5)$$

The operator should make himself thoroughly familiar with these formulæ; they are very simple, and when once fixed in the mind, the ship calculations become a very simple matter, and will obviate years in studying the rules and tables of various authors, with the accompanying vague notion of the reason why the different operations are performed. With these formulæ, any table of ship calculations can be analyzed, whether by trapezoidal or Simpson's rules, by supplying the symbols opposite the figures; and with them any tables may be departed from, and new tables constructed, or the calculations can be made, without tables, directly from the formulæ. Probably the greatest loss of time on the part of the operator is in trying to work out his problem by following the operations in some similar table already worked out, or in a text-book, without always understanding the work, which is a source of error and delay.

Table VIII is subject to the same remarks as for the preceding table. The values of Σy must first be found as in Table I.

Also, in combination tables, for the next higher or lower water-line, the method of adding or subtracting the half sums of end ordinates may be employed.

EXAMPLE.

TABLE VIII.—VERTICAL POSITION OF CENTER OF BOUYANCY BY FOUR METHODS. STEAM TUG OF TABLES I TO V.

Numbers of water-lines.	Σy from Table III, column 5.	n	$n\Sigma y$	A from Table III, column 6.	nA
5	(½) 41.1	0	(½) 0.0	(½) 753.7	(½) 0.0
4	74.8	1	74.8	1371.8	1371.8
3	65.7	2	131.4	1204.9	2409.8
2	51.6	3	154.8	946.3	2838.9
1	(½) 12.9	4	(½) 51.6	(½) 236.6	(½) 946.4
$\Sigma\Sigma y = 246.1$		$\Sigma(n\Sigma y) = 412.6$		$\Sigma A = 4513.3$	$\Sigma(nA) = 7566.9$
w = 2 feet.		$\frac{w\Sigma(n\Sigma y)}{\Sigma\Sigma y} = \frac{2\times412.6}{246.1}$		$\frac{w\Sigma(nA)}{\Sigma A} = \frac{2\times7566.9}{4513.3}$	
s = 9.17 feet		$z = 3.35$		$z = 3.35$	
V_5 = 9027 cubic feet.		$\frac{2sw^2\Sigma(n\Sigma y)}{V} = \frac{8\times9.17\times412.6}{9027}$		$\frac{w^2\Sigma(nA)}{V} = \frac{4\times7566.9}{9027}$	
		$z = 3.35$		$z = 3.35$	

CENTER OF GRAVITY OF BOTTOM PLATING.

The weight of this plating being proportional to the volume occupied, evidently its center of gravity coincides with the center of form. Also since both sides are symmetrical, the center of gravity falls at a point in the diametral plane which divides the vessel into two symmetrical halves. This point is determined as shown on Fig. 1, page 276.

Fig. 1 shows a single half section of the ship, and AB is the half-girth. Divide the half-girth into four equal parts at b, c, and d. The center of gravity of each of these parts is nearly at its center. Join the centers of the two upper parts, and those of the two lower ones, and bisect each joining line in g_1 and g_2. The points g_1 and g_2 represent the combined center of gravity of the two lower parts and the two upper parts respectively. Join g_1 and g_2 and bisect in g_3. The point g_3 represents the center of gravity of the four parts of the half-girth AB.

If we draw g_3G parallel to water-line, G will be the center of gravity of the whole girth of the section, the two sides being symmetrical. Thus the

distance of the center of gravity of the half-girth from water-line is the same as that of the whole girth, and the same is true of its distance from the midship section; so we will deal with half-girths for the sake of simplicity. The moment of the half-girth AB about water-line is evidently equal to its length multiplied by the distance from its center of gravity to water-line $= AB \times g_3C$. Every section on the body plan must be treated in this fashion to determine graphically its center of gravity and the distance of its center of gravity from water-line. It must not be overlooked that we are getting the moments of the area of the plating surface which is proportional to its weight, and the problem becomes similar to that where it is required to find the center of gravity of a plane surface bounded by a curve, if we only consider that the ordinates in this case are curved instead of

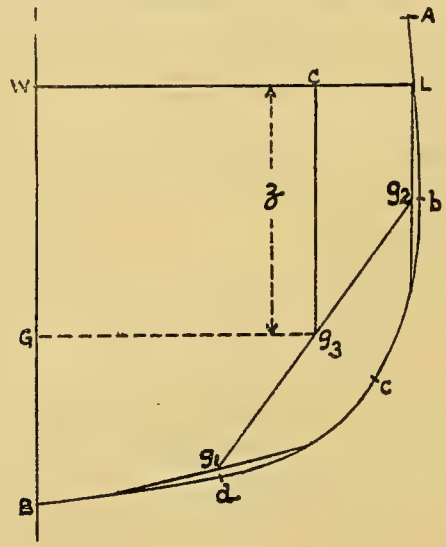


Fig. 1.

straight. That is, the half-girths are curved ordinates of the plating surface, and are equivalent in lengths to the straight ordinates of the developed surface if it were rolled out flat from the keel. Let us represent the half-girths by the curved ordinates y_1, y_2, and y_3, for the first, second, third, etc., sections. Let the distances g_3C from the center of gravity of each half-girth to water-line be represented by z_1, z_2, z_3, etc., for the different sections.

As in a plane surface, the curved element of surface $= ydx$, where y is the curved ordinate and x is the fore and aft distance. The elementary moment about water-line $= ydx.z$, and the sum of all the elementary moments is $\int ydx.z$. Then evidently

$$\underline{z} = \frac{M}{A} = \frac{\int ydx.z}{\int ydx} = \frac{s\Sigma yz}{s\Sigma y} = \frac{\Sigma yz}{\Sigma y} \qquad (1)$$

$\underline{z}$ is the distance of the center of gravity of the outside plating below water-line, where water-line usually represents the load water-line. This finds the vertical position of the center of gravity. It is well to remember we are dealing with surface and not volume, and not confuse the two, as is frequently done in some text-books in vogue.

To find the longitudinal center of gravity of outside plating, however, we have the elementary moment $ydx.x$ and derive the value of $\underline{x}$ by the same method as in the case of a curvilinear area, previously explained, viz.,

$$\underline{x} = \frac{s\Sigma ny}{\Sigma y} \tag{2}$$

keeping in mind the difference in the nature of the ordinates.

Some authors correct the half-girth ordinates, increasing them slightly to compensate for the additional surface not developed in expanding the plating transversely, but not longitudinally. This may be done but the result will be sufficiently accurate without it, particularly with regard to the position of the center of gravity. The idea in correcting ordinates is to be able to get the true surface at the same time, by which to get the weight of the plating. It is much more accurate and expeditious to calculate the center of gravity from the simple, uncorrected half-girths, which makes an inappreciable error in the location of center of gravity; and to calculate the area of the surface from a more exact method, since the error in weight by the former method might be more appreciable.

Example.—A ship is divided into fifteen sections at a common interval of 16 feet apart. The half-girths are as entered in Table IX. The center of gravity of each half-girth is found by the foregoing graphic method, and its distance z, below the load water-line is entered in the table. Find the vertical and longitudinal positions of the center of gravity of bottom plating.

The figures of Table IX may be further simplified by using an auxiliary water-line below the load water-line, but just above the highest position of any of the values of z. Suppose the fifth water-line falls at 7 feet below the load water-line, we can locate z with regard to this water-line by measuring the various values of z below it. That is the equivalent of subtracting 7 feet from each value of z. The values of z to be used in the table will be 0.3, 1.7, 2.9, 4, 4.9, 5.2, 5.7, 5.7, 5.5, 5.1, 4.6, 3.9, 3.5, 3.0, instead of the larger figures. This simplifies the multiplications and additions in the column yz, by handling smaller figures. To the vertical distance thus found we can add 7 feet to get the distance from the load water-line, which will give the same result as in the table.

TABLE IX.—LONGITUDINAL AND VERTICAL POSITIONS OF CENTER OF GRAVITY OF OUTSIDE PLATING, $\underline{x} = \frac{s\Sigma ny}{\Sigma y}$, $\underline{z} = \frac{\Sigma yz}{\Sigma y}$, $s = 16$ FEET.

Numbers of sections.	Half-girths.	Intervals from midship section.	Products for intervals.	Center of gravity of each below load water-line.	Products for vertical functions.
	y	n	ny	z	yz
1	$(\frac{1}{2}) = 12.8$	7	$(\frac{1}{2}) = 89.6$	7.3	$(\frac{1}{2})$ 93.4
2	30.0	6	180.0	8.7	261.0
3	34.1	5	170.5	9.9	337.6
4	38.7	4	154.8	11.0	425.7
5	41.6	3	124.8	11.9	495.0
6	42.9	2	85.8	12.2	523.4
7	44.5	1	44.5	12.7	565.2
8	44.5	0	850.0	12.7	565.2
9	44.5	1	44.5	12.7	565.2
10	43.7	2	87.4	12.5	546.2
11	42.4	3	127.2	12.1	513.0
12	40.5	4	162.0	11.6	469.8
13	38.2	5	191.0	10.9	416.4
14	36.1	6	216.6	10.5	379.0
15	$(\frac{1}{2}) = 17.6$	7	$(\frac{1}{2}) = 123.2$	10.0	$(\frac{1}{2}) = 176.0$
			951.9		
$\Sigma y = 552.1$		$\Sigma ny = -101.9$ $\frac{s\Sigma ny}{\Sigma y} = \frac{-101.9 \times 16}{552.1}$ $\underline{x} = -2.9$ feet.		$\Sigma yz = 6332.1$ $\frac{\Sigma yz}{\Sigma y} = \frac{6332.1}{552.1}$ $\underline{z} = 11.4$ feet.	

All these methods to shorten and simplify the work are of the greatest value.

The approximate area of the surface of outside plating may be gotten from the formula, $A = 2s\Sigma y$ where y is the half-girth and A the area of both sides:

The wetted surface may be calculated by this formula, using the proper value of y, which is generally accurate to within two tenths of one per cent.

MOMENT OF INERTIA AND METACENTER.

Let us take the usual nomenclature,

I = moment of inertia about a given axis.
I_0 = moment of inertia about a parallel axis through center of gravity of the figure.
h = depth of the figure in a line perpendicular to the axis.
d = perpendicular distance between the axes corresponding to I and I_0.
A = area of the figure.

We know from the text-books the following equivalents

$$I_0 = \frac{1}{12} Ah^2 \tag{1}$$

and

$$I = I_0 + Ad^2. \tag{2}$$

1. *Longitudinally.*—If we take the moments about the y axis, of the elementary areas ydx, we will have

$$I = \int x^2 ydx \tag{3}$$

The term corresponding to the value of I_0 drops out of (3) because the area of the strip is so small, and the value of h^2, which is equal to dx^2, is so small that I_0 is negligible.

If now, for calculating purposes, we divide the area into a number of sections by ordinates having a common interval, s, the working formula will become

$$I = s\Sigma x^2 y \tag{4}$$

x is the distance of the ordinate from the y axis, and if we let n be the number of intervals the ordinate is removed from this axis, we will have for any given ordinate $x = ns$; that is, for ordinates 1, 2, 3, 4, etc., stations away from this axis, the value of x is s, $2s$, $3s$, $4s$, etc., respectively. Thus $x^2 = n^2s^2$, in which s is constant; therefore, the formula becomes

$$I = s^3\Sigma n^2 y \tag{5}$$

2. *Transversely.*—To find the moment of inertia of an area generated by the elementary strips ydx about the x axis we have, since

$$I_0 = \frac{Ah^2}{12} = \int \frac{ydx \times y^2}{12}$$

and

$$Ah^2 = \int ydx \times \left(\frac{y}{2}\right)^2$$

$$\therefore \quad I = \int \left(\frac{1}{12} + \frac{1}{4}\right) y^3 dx.$$

$$I = \int \frac{1}{3} y^3 \, dx \tag{5}$$

Dividing the figure into sections by the common interval, s, we have the working formula

$$I = \frac{s}{3} \Sigma y^3 \tag{6}$$

It is necessary to remember that

$$\Sigma y^3 = \tfrac{1}{2} y_1^3 + y_2^3 + y_2^3 + \ldots \tfrac{1}{2} y_n^3.$$

The error is frequently made of cubing one-half the end ordinates thus,

$$\Sigma y^3 = \left(\frac{y_1}{2}\right)^3 + y_2^3 + \ldots \left(\frac{yn}{2}\right)^3,$$

but this error should be borne in mind and guarded against.

VALUE OF BM.

We know this value, as ordinarily derived, to be

$$BM = \frac{I}{V} \tag{1}$$

For a figure, about its x axis as a base, we have found $I = \frac{1}{3} \int y^3 dx$; in the case of a water-line having symmetrical areas on both sides of the x axis, $I = \frac{2}{3} \int y^3 dx$. Hence

$$BM = \frac{\frac{2}{3} \int y^3 dx}{V} \tag{2}$$

Putting this into working form, we have

$$BM = \frac{\frac{2}{3} s \Sigma y^3}{V} \tag{3}$$

This form, using volume and water-line ordinates, is the more usually employed, and is preferable.

The other form, to calculate directly from the ordinates, is obtained thus

Since $$V = 2sw\Sigma\Sigma y$$

$$BM = \frac{\Sigma y^3}{3w\Sigma\Sigma y} \tag{4}$$

EXAMPLE.

Given the following ordinates of half the load water-line, 0.4, 3.4, 6.8, 9.0, 10.2, 10.4, 10.4, 10.2, 9.8, 8.2, 7.2 feet, which are those of the steam tug of Table IV, Column 11. Find I and BM by formulæ (7) and (8) using the values of V and $\Sigma\Sigma y$ as already found in those tables. (See Table X).

SUMMATION OF FORMULÆ.

$$A = 2s\Sigma y \tag{1}$$

$$S = 2w\Sigma y \tag{2}$$

$$V = s\Sigma S = w\Sigma A = 2sw\Sigma\Sigma y \tag{3}$$

Center of gravity of water-line, $\underline{x}$ $$\left\{\begin{aligned} &= \frac{2s^2\Sigma ny}{A} \\ &= \frac{s\Sigma ny}{\Sigma y} \end{aligned}\right. \tag{4}$$

Center of gravity of half water-line, $\underline{y}$ $$= \frac{\Sigma y^2}{2\Sigma y} \tag{5}$$

Center of buoyancy (longitudinally), $\underline{x}$ $$\left\{\begin{aligned} &= \frac{s\Sigma nS}{\Sigma S} \\ &= \frac{s^2\Sigma nS}{V} \\ &= \frac{s\Sigma(n\Sigma y)}{\Sigma\Sigma y} \\ &= \frac{2s^2w\Sigma(n\Sigma y)}{V} \end{aligned}\right. \tag{6}$$

$$\text{Center of buoyancy (vertically), } \underline{z} \begin{cases} = \dfrac{w\Sigma nA}{\Sigma A} \\ = \dfrac{w^2\Sigma nA}{V} \\ = \dfrac{w\Sigma(n\Sigma y)}{\Sigma\Sigma y} \\ = \dfrac{2sw^2\Sigma(n\Sigma y)}{V} \end{cases} \tag{7}$$

$$\text{Center of gravity of outside plating, } \begin{cases} \underline{x} = \dfrac{s\Sigma ny}{\Sigma y} & (8) \\ \underline{z} = \dfrac{\Sigma yz}{\Sigma y} & (9) \end{cases}$$

$$I = \frac{s}{3}\Sigma y^3 \tag{10}$$

$$BM \begin{cases} = \dfrac{\frac{2}{3}s\Sigma y^3}{V} \\ = \dfrac{\Sigma y^3}{3w\Sigma\Sigma y} \end{cases} \tag{11}$$

TABLE X.—TO FIND I AND BM FROM ORDINATES AND V.

	Length of ordinates.	Cubes of lengths.
	y	y^3
	0.4	0.1
	3.4	39.3
	6.8	314.4
	9.0	729.0
	10.2	1,061.2
	10.4	1,124.9
	10.4	1,124.9
	10.2	1,061.2
	9.8	941.2
	8.2	551.4
	7.2	373.2
From Table III $\begin{cases} V_5 = 9{,}027 \\ \Sigma\Sigma y = 246.1 \\ w = 2 \text{ feet.} \\ s = 9.17 \text{ feet.} \end{cases}$	Sum.	7,320.8
	$\frac{y^3_1 + y^3_{11}}{2}$	186.6
	Σy^3	7,134.2

$$I = \frac{2s}{3}\Sigma y^3 = \frac{2 \times 9.17 \times 7{,}134.2}{3} = 43{,}613.7$$

$$BM = \frac{\frac{2s}{3}\Sigma y^3}{V} = \frac{43{,}613.7}{9{,}027} = 4.8 \text{ feet.}$$

or,

$$BM = \frac{\Sigma y^3}{3w\Sigma\Sigma y} = \frac{7{,}134.2}{3 \times 2 \times 246.1} = 4.8 \text{ feet.}$$

DISCUSSION.

THE PRESIDENT:—The paper by Naval Constructor T. G. Roberts on "Ship Calculations; Derivation and Analysis of Methods," is now upon for discussion.

PROF. WILLIAM HOVGAARD, *Member:*—The author of this paper has given to the student an exceptionally clear exposition of the formulas underlying ship calculations and of the principal methods in carrying them out. The comparison between the pure French method of applying the trapezoidal rule and that used in the United States Navy is interesting, and one cannot but admit that the French "subtraction" method appears shorter and simpler than the "addition" method.

There is one point on which I do not quite agree with the author, viz., his remarks on page 277 that "It is much more accurate to calculate the longitudinal center of gravity of the shell plating from the simple uncorrected halfgirths." The longitudinal obliquity of the surface and the structural features of the shell are, in fact, rarely symmetrical and may often influence the position of the center of gravity in a longitudinal direction. Since a correction of the girth for obliquity should in any case be made in the weight calculation of the shell, no additional work is involved in using the augmented girth in the calculation for longitudinal center of gravity.

This calculation is best carried out by first constructing a curve for the augmented girths allowing not only for obliquity, but also for overlaps at the seams and for deviations from the standard thickness of the plating, including doubling at the ends. By means of the integraph or an integrator, the weight and longitudinal center of gravity can then be easily determined, irrespective of the irregularities of the resulting diagram. The accompanying Fig. 1 shows the general character of such a diagram.

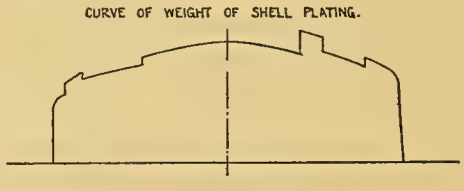


FIG. 1

The obliquity is most readily determined by measuring with a planimeter the area on the body plan between every second station. Dividing each area so obtained by the girth of the intermediate station, we obtain an approximate value of the mean distance between the two stations, enclosing the area in their transverse projection. This mean distance, divided by twice the longitudinal spacing of consecutive stations gives the mean value of the tangent of the angle of obliquity of the

surface at the intermediate station. Now the augmented girth of the intermediate station may be obtained by multiplying the girth, as measured on the body plan, by the secant of this angle. (Fig. 2.)

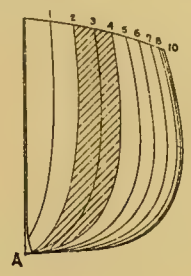


FIG. 2

Referring to Fig. 2, the obliquity θ on station 3, for instance, is found from:

$$\tan\theta = \frac{\text{area } A24}{2s(\text{girth } 3)}$$

where s is the longitudinal spacing of the stations.

I do not think that this method of finding the obliquity is known or applied outside my classes in naval construction; it was suggested to me some years ago by Naval Constructor McEntee, when he was a student of the Massachusetts Institute of Technology, and gives, I believe, as good an approximation as any other method.

NAVAL CONSTRUCTOR ROBERTS (Communicated):—With reference to Professor Hovgaard's remarks, I yield, of course, to the point of further accuracy if one wishes to carry it to that degree of refinement, and am very glad he has seen fit to make the additions contained in his discussion. It is evident from my language that the analysis I offered was made particularly to fit only the usual calculations of the position of the center of gravity of the bottom plating, which permits of the utmost facility as well as what has usually been considered a sufficient degree of accuracy to all intents and purposes.

THE PRESIDENT:—The next paper is entitled "Some Applications of the Principles of Naval Architecture to Aeronautics," by Naval Constructor William McEntee.

SOME APPLICATIONS OF THE PRINCIPLES OF NAVAL ARCHITECTURE TO AERONAUTICS.

By Naval Constructor William McEntee, U. S. N., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1911.]

Considering the essential similarity of the problems involved in aeronautics and in naval architecture, it is a singular fact that with the development of the first, both theoretically and experimentally, but little has been done by the trained naval architect. So far as known, none of the men whose names are well known as leaders in this field have been educated in its kindred and elder branch of engineering.

There is no doubt that many difficulties could have been avoided by the earlier experimenters and many practical advantages can be gained to-day by those engaged in aeronautical engineering through the use of some of the fundamental principles of naval architecture. For example, Langley has stated in his memoirs, written after a number of years of investigation and experiment, that as regards the stability of an aeroplane, longitudinal stability is difficult to obtain, but that transverse stability is comparatively an easy matter. Practical experience shows the facts to be the reverse. There were no really successful aeroplanes until sufficient transverse stability had been obtained by the introduction of warping wings, or other similar devices. At one time Langley also thought that frictional resistance was but a small part of the total resistance to the motion of plane surfaces through the air at small angles of inclination, and therefore, that as the speed of a given aeroplane increased beyond a certain amount the power required to propel it would continually decrease. The naval architect always on guard as regards the transverse stability of ships and with his knowledge of frictional resistance of water and increase of power required with increase in speed of a ship would hardly have fallen into these errors.

As in naval architecture, the practical elements dealt with in aeronautics are: Weight or displacement, buoyancy, stability, resistance, propulsion, and speed. For higher theoretical investigations the mathematics of stream lines or fluid motion are equally applicable to each.

At the present time the aeroplane appears to promise greater returns in usefulness and in any case its development has recently been so rapid that it attracts more interest than does the dirigible. For this reason the present discussion will be limited to aeroplanes and deal only with questions of stability and propulsion.

STABILITY.

As with the ship, the stability of an aeroplane may be considered as longitudinal and transverse, both depending on the relation between the resultants of the supporting forces, and the position of the center of gravity. And like the ship, the aeroplane has metacenters for both directions.

Let us consider first the longitudinal stability of a rectangular plane moving in the air at small angle of incidence.

If x be distance of the center of pressure from the forward edge we have, as with the rudder,

$$x = l(0.195 + 0.305 \sin i)$$

where l is the depth of the plane in the direction of motion and i the angle of incidence. If a weight be added to the plane so that the center of gravity of the whole is at a distance, say $\frac{1}{4}l$, from the leading edge, the plane will assume a position of equilibrium at an angle of incidence of approximately 10 degress, the center of pressure and center of gravity being in coincidence.

If for any reason the angle of incidence is increased, the center of pressure will move farther away from the leading edge and a righting movement will result, tending to decrease the angle of incidence to 10 degrees, similarly, if the angle is decreased below 10 degress an opposite righting moment will follow, tending to bring the plane back to its position of equilibrium. This condition is readily seen to be similar to that of a ship, which, if stable, tends, when inclined from its position of equilibrium, to return to that position, the righting moment being, $GM \sin i$ where GM, is the distance between the center of gravity and the metacenter.

The metacenter of the plane under consideration can be found in the following manner:

The normal pressure P, on the moving plane is given by

$$P = \frac{KAV^2 \sin i}{0.195 + 0.305 \sin i}$$

where K is a constant depending on the density of the air, A the area of the plane and V its velocity.

The moment of P about the leading edge is

$$Px = KAV^2 l \sin i. \tag{3}$$

The moment of the total weight W about the same axis is $\frac{Wl}{4} \cos i$ and

where $i=10°$ we have $\frac{Wl}{4}\cos i = KAV^2 l \sin i$ or $KAV^2 = \frac{W}{4}\cot i = 1.35W$.

Substituting in (3) $Px = 1.35\ Wl \sin i$.

If the inclination is changed the righting moment will be the difference between the moments of the weight and the moment of the pressure whence:

$$1.35\ Wl \sin i - 0.25 Wl \cos i = Wl\,(1.35 \sin i - 0.25 \cos i). \qquad (4)$$

If θ be the angle of incidence at the position of equilibrium and this be increased by a small angle, α, we shall have from (4) the righting moment.

$$M = Wl\,[1.35 \sin(\theta+\alpha) - 0.25 \cos(\theta+\alpha).] \qquad (5)$$

If GM be the metacentric height of the plane at the angle θ, then the righting moment when further inclined by the small angle α, will be:

$$GM \times W \sin \alpha = Wl\,[1.35 \sin(\theta+\alpha) - 0.25 \cos(\theta+\alpha).] \qquad (6)$$

(or)
$$GM = l\,(1.35 \cos\theta + 0.25 \sin\theta). \qquad (7)$$

Under the conditions assumed θ is approximately 10 degress. Using the value in (7) gives a metacentric height

$$GM = 1.37l.$$

For a plane 6 feet in depth and of the usual width of an aeroplane this would give a longitudinal metacentric height of about 8.2 feet.

It is to be noted, however, that the righting moment is not equal for equal changes up and down from the position of equilibrium. This will be seen from an inspection of equation (3). Increase in the angle of inclination causes an increase in the total pressure and results in a larger righting moment than is the case for decrease in the angle of incidence.

This conclusion seems to be confirmed by experience with actual aeroplanes which have failed because of insufficient fore and aft stability. They fall head first and not tail first.

With regard to transverse stability of the plane considered above it is obvious that transverse inclination will produce no change in the transverse position of the center of pressure and as the center of gravity is assumed to be at the center of pressure, there is no righting moment to resist such inclination. The transverse stability is nil and if inclined to one side or another the plane will fall sidewise. This would be modified somewhat, however, by the resulting transverse velocity having some tendency to right the plane.

In a biplane of the ordinary type with distance of 6 feet between planes, the center of gravity is sometimes as much as 12 inches below the center of the buoyancy taken as midway between the center of pressure of the upper and the lower planes. This of course gives a transverse metacentric height of about 12 inches for such machines. It is dangerous, however, to place the center of gravity very low because of the pendulum action tending to capsize the aeroplane when its motion is accelerated or retarded, and for that reason it is not possible to get satisfactory transverse stability simply by placing weights low.

From the foregoing discussion of the stability of plane surface in motion, it appears clear that the stability in the direction of motion is much greater than that at the right angles to that direction.

On account of the greater proportional supporting effect, aeroplanes, as you know, are built with curved surfaces. It remains to determine what effect this curvature has on the fore and aft stability and what modifications in the conclusions as regards the stability of plane surfaces are necessary.

The variation of the position of the center of pressure with changes in the angle of incidence for the curved surface differs markedly from that for the plane surface for similar changes in the angle of incidence. The exact law for curved surfaces is not definitely known but its general character can be indicated.

In Fig. 1 are shown curves giving the distance of the center of pressure from the leading edge of a plane surface and of a curved surface at different angles of incidence.

For the plane it will be seen that the distance increases from about 0.2 at zero inclination to 0.5 at 90 degrees, while for the curved surface the center of pressure is somewhere near the middle at zero inclination, moves forward as the inclination increases to about 5 degrees, and then backward until it is in the same position as for a plane at an inclination of 90 degrees. The reason for this difference will be seen by referring to Figs. 2 and 3, Plate 141, which represent the side views of curved and plane surfaces respectively. The small arrows indicate in general the direction of the forces acting on the two. The large arrows indicate the resultant forces in the two cases. At the angle of incidence shown the forces act downward near the leading edge of the covered surface and upward on the plane. This causes the position of the resultant, or the center of pressure of the first to be considerably farther from the leading edge than for the second.

The conclusion to be drawn from the difference shown in Fig. 1, is that for a curved surface after the angle of incidence is decreased below a certain point, the center of pressure moves backwards instead of moving forward

and the surface becomes unstable. The forces acting then tend further to reduce the angle of incidence until the supporting forces become nil. If, however, the angle of incidence is increased above the critical point, the action and stability for the curved surfaces is similar to that for a plane one. It therefore seems that the fore and aft stability of the ordinary aeroplane is less than it would be if its supporting surfaces were plane. It is probable that in some of the cases where aviators making vol-planes at sharp angles of descent, have lost control of their machines and been unable to right them, are explainable by the fact that the angle of incidence has gotten so far below the critical angle that the horizontal rudder was insufficient to restore the equilibrium.

Transverse stability for the curved surface does not differ from that for the plane.

At the present transverse stability of aeroplanes depends almost entirely on the skill of the aviator in flexing the wings or ailerons which are in effect horizontal side rudders.

If automatic means can be provided whereby the flexing of the wings can be made proportional to and simultaneous with the transverse inclination of the aeroplane, the resulting metacentric height can be made relatively very large and satisfactory stability will be insured.

It may be of interest to note here that in the Wright aeroplane, some use is made of the principle of distributing weights transversely so as to increase the natural period of rolling as the motor is some distance on one side of center line and the operator and passenger a corresponding distance on the other side.

PROPULSION.

Given a reliable motor not excessive in weight the question of propulsion reduces practically to the selection of a propeller of proper form and dimensions for the necessary thrust at the estimated speed. Examination of the literature on the subject published either in books or in aeronautical journals discloses wide diversity of opinions and theories as to the action of air propellers and the different elements affecting their efficiencies. There is also a great dearth of reliable data taken from actual trials of model or full size propellers in motion. The diversity of theories can readily be understood by those who have struggled with similar questions as regards the water propeller, and Marine Engineers will scarcely be surprised to learn that the efficiencies obtained by the propellers in use on some of the best known types of aeroplanes, vary from somewhere below 50 per cent. to the vicinity of 70 per cent.

Of the well known types there is no doubt that the Wright propeller is the most efficient. It has an efficiency which is equal, if not superior to that reached by the most successful marine types. To engineers who are familiar with the inherent difficulties of the subject the Wrights' success with the propeller gives an indication of the high ability of these pioneers in practical navigation in heavier-than-air machines.

The Society's Transactions for 1906, contains a paper on "The Limit of Propeller Efficiency," by the writer of the present paper. The principles made use of at that time in dealing with the water propeller seem equally applicable to the air propeller, and possibly are of sufficient interest to warrant a discussion along the same lines.

For those who may not have at hand the 1906 paper, the following is given again, simply substituting "air" for "water" in the notes:

Let V_1 be the speed of advance, in feet per second; V_2 the sternward velocity imparted to the air accelerated by the action of the propeller, and A the area of the circle swept by the tips of the propeller blades.

Consideration makes it appear that the amount of air displaced per second is $A(V_1+V_2)$.

Its mass is $$\frac{W}{g}A(V_1+V_2).$$

The constant force or thrust which must be applied to impart the velocity, V_2 is

$$T=\frac{W}{g}A(V_1+V_2)V_2 \tag{1}$$

Useful work $$Wu=\frac{W}{g}A(V_1+V_2)V_2V_1 \tag{2}$$

Gross work $$Wg=\frac{W}{g}A(V_1+V_2)V_2V_1+\frac{W}{2g}A(V_1+V_2)V_2^2. \tag{3}$$

the last term being the expression for the kinetic energy imparted to the air.

Efficiency $$e=\frac{Wu}{Wg}=\frac{V_1}{V_1+\frac{V_2}{2}} \tag{4}$$

Solving for V_2 in (1) and substituting in (4):

$$e=\frac{4}{3+\sqrt{\frac{4g\,T}{W\,A\,V_1^2}+1}} \tag{5}$$

Next, substituting $\frac{\pi d^2}{4}$ for A and the numerical values for g and W* and reducing V_1 in foot-seconds to V miles per hour.

$$e = \frac{4}{3 + \sqrt{\frac{1020\ T}{V_2 d_2} + 1}} \tag{6}$$

This formula expresses the theoretical relation which exists between the efficiency, thrust, speed of advance, and diameter in feet.

For a given speed of advance and given diameter, e may be computed for varying values of T and the results plotted as ordinates on thrusts as abscissæ. This curve will show how the efficiency falls off as the thrust is increased.

In Fig. 4, Plate 142, the full line is the theoretical limit of efficiency for a propeller 25 inches in diameter moving with different thrusts at a speed of 2000 feet per minute or 22.7 miles per hour. This particular size and speed is selected because there are available accurate data for such a propeller.

On the same figure the lowest line shows the actual efficiencies obtained with a 25-inch two-bladed wooden propeller at the same speed, the data being taken from a recent report of the "British Advisory Committee on Aeronautics." The dimensions of the propeller are shown in Fig. 5, Plate 142.

In Fig. 4, Plate 142, it will be noted that though the actual efficiency is much less than that indicated as the limit by theory, the curves are, except at low thrust, sensibly parallel and seem to bear some relation one to the other.

It was to be expected of course that the curve of actual efficiency would be below that obtained by theory as in the deduction of the latter but one cause of loss of energy is allowed for, that is the kinetic energy lost in the propeller race. With a perfect and frictionless propeller this would be the only loss. With actual propellers, however, there are additional losses due to the following causes:

(1) Surface friction, (2) resistance due to shape of blade section, (3) rotation velocity of race, (4) lack of uniformity of sternward velocity of race, (5) resistance of hub, (6) reduction of effective cross-section of race on account of hub.

For this particular propeller the pitch ratio is only 0.54 and the high number of revolutions compared with the speed of advance naturally results in high friction and head resistance losses. A marine propeller of the best

*The weight of air is taken as at 70° F. and a humidity of 70% under which conditions a cubic foot weighs .0746 lbs.

present form and of the same pitch ratio could hardly be expected to give a much better efficiency.

Inspection of equation (6) indicates that for a given thrust and speed the larger the diameter the better for efficiency, and this would be true but for friction and similar losses. If the propeller is made small the slip loss is large and if made large the friction loss is excessive. The best diameter is a compromise between the two extremes.

In the paper referred to above the writer proposed the formula $d=\frac{\sqrt{T}}{V}$ where T is the thrust in pounds and V the speed in knots as giving about the best diameter for a marine propeller. If allowance is made for the difference in the densities of air and water and V is changed to miles per hour the corresponding formula for the air propeller is

$$d=\frac{33\sqrt{T}}{V}$$

For a thrust of 100 pounds and at a speed of 40 miles per hour this gives,

$$d=\frac{33\sqrt{100}}{40}=8\tfrac{1}{4}\text{ feet.}$$

This result agrees remarkably well with what the Wrights use for this thrust and speed. They use an $8\frac{1}{2}$-foot propeller under these conditions. The pitch of their propeller is about 1.3 d, and in order to use this pitch with a fast running motor it is interesting to note that they make use of a reduction gear, the principle being similar to that of reduction gears which are now beginning to be used for marine propulsion.

For the best type of marine propellers the actual efficiency obtained is about 80 per cent of that indicated as the limit by theory. If equation (6) is multiplied by 0.80 we have

$$e=\frac{3.2}{3+\sqrt{\frac{1020T}{V^2d^2}+1}} \tag{7}$$

This indicates what should be expected from a good air propeller provided the experience with marine propeller can be extended to the latter. The curve corresponding to (7) is shown in Fig. 4, Plate 142.

A full size two-bladed air propeller tested at Vickers' on a whirling table gave the following results:—

$d = 15$ feet, $V = 36$ miles per hour, thrust $= 864$ pounds, efficiency $= 64$ per cent. If these values of d, V, and T, are substituted in (7) above we have:

$$e = \frac{3.2}{3 + \sqrt{\frac{1020 \times 864}{1296 \times 225} + 1}} = 63.9\%$$

The actual efficiency and that computed by formula (7) are practically identical. The data were not published completely but it is probable that at a thrust of about 280 pounds, the particular propeller had an efficiency in the vicinity of 72 per cent.

Finally from the data available it seems clear that experience with the water propeller and methods used in its design can be extended with advantage to the design of air propellers.

DISCUSSION.

Capt. W. Irving Chambers, U. S. N., *Member* (Communicated):—I am glad to see such a creditable paper on this subject by a Naval Architect and I earnestly hope that the future pages of these transactions will glow with further evidences of an appreciation of the scientific work needed in the development of aviation.

We have not heard enough about aviation from Naval Architects as yet and I presume it is because the science is advancing with such rapid strides that it requires practically the undivided attention of anyone who desires to keep up with it and to assist in its development.

A year or two ago aviation took such a prominent place in the public eye that a great many people began to look for its speedy adaptation to commercial uses and all sorts of extravagant predictions were made, but after the first blush of excitement, temperate views began to prevail and the public realized that the science was still in its infancy. Aeronautical periodicals have recently inquired, "What is the matter with Aviation?" In his reply to this Mr. Hugo Gibson gave an answer which accords with my views and I quote the following extract from him, "Aviation is a science, and for its advancement requires an army of scientific workers, it is a serious business and when tackled by serious minded engineers, who know how to select their designs, forms, material, methods and labor, and who are relieved from the necessity of prostituting their product by parsimonious economy, it will become a standard money-making business in the provision of the many thousands of machines which will be used . . . on land and water . . . ."

Of course we realize that the full development of aviation depends more upon the motive power than upon the architecture of the planes or the sustaining structures, but it is noticeable in some of the latest foreign and domestic designs that "the influence of stream lines or of fluid motion," referred to by Mr. McEntee, is beginning to show up of great importance and these later designs reflect also the influence of the scientific laboratories and the results of more scientific study by those accustomed to deal with engineering problems by truly scientific methods.

The more I look into this subject, the more I wonder that Naval Architects have not been more in evidence in the development of aviation, especially in connection with the hydroplane. I know it is a common impression among aviators abroad that the hydroplane is an unnecessary if not an undesirable appendage. However, I regard it not only as of great importance in developing the aeroplane for naval purposes, but I believe it will be one of the chief factors in the future progressive development of aviation generally for sport and for commerce.

My experiences with Mr. Glenn H. Curtiss have steadily strengthened my conviction that we will soon have a suitable machine to use from ships by which the training of aviators may progress systematically from the ship as a base, but to illustrate how readily the hydroplane lends itself as a factor in development, I will mention the experience of Mr. Starling Burgess, of Marblehead, Mass. He is a boatbuilding genius who has transformed his nautical plant into an aeroplane factory. This plant is situated in a rather cramped space on a rocky water front with the nearest aviation field many miles away, as is usually the case with desirable factory sites. The hydroplane naturally appealed to him, not only because of his natural instincts as a skillful boat builder, but because the beautiful harbor at Marblehead provided for him an ideal aviation field right at his door steps. He has now succeeded in developing, on scientific lines, a beautiful hydroplane, for the Burgess-Wright machine, which adds less than 40 pounds to weight and increases resistance in flight very little. Now he is able to instruct his pupils over the water, with the factory as a base, with less danger to them than when teaching on land and with practically no expense in the matter of repairs, which expense account was considerable under the old method.

The architecture of the aeroplane has always appealed to me as a boat-builder's, or a naval architect's, problem and I am still hoping that Mr. Nat Herreschoff or his sons, will catch the inspiration under the spur of the advantages and fascination of the hydroplane attachment.

Already some hydroplane model tests have been made in the naval tank at the Washington Navy Yard and this place is eminently suited not only for model tests in water but for model tests in air. I have no doubt that our brilliant staff of naval architects will soon be able to take hold of this laboratory work in earnest and that, through them, the science of aviation in this country will receive as much advancement as has the science of shipbuilding by the same agency.

In regard to the efficiency of propellers I find a half suppressed but a strong belief among aeroplane builders that there is much to be expected from improve-

ment in this direction and I have heard very good arguments to foster a hope that the present form of air propeller may be supplanted by something radically different and more suited to our purposes.

I differ slightly from the author of this excellent paper with respect to Langley's comparison between longitudinal and transverse stability. I think Langley's statement stands as a wonderful tribute to his analytical genius. At first I had the author's idea of greater difficulty in maintaining transverse stability and I think it is a common tendency for beginners to regard a low center of gravity as desirable. I have noted that aviators on learning to fly are at first more concerned with the transverse than with the longitudinal control, very often to their discomfiture. It takes them some time to gain sufficient confidence to bank, or tip, the machine properly in making a turn. The tendency at first, especially with those using ailerons, is to maintain the level in turning, thereby making a long tactical diameter and allowing the machine to slide off to leeward. But as soon as they get accustomed to the feeling of safety in banking during a turn and while running across the wind, they show an apparent contempt for transverse stability even to the point of recklessness, as is often seen during a spiral volplane, when the wings are sometimes tilted so as to appear nearly perpendicular to the earth's surface. Nature seems to have provided for stability, or rather balance, by making a bird's wing long transversely and narrow longitudinally, for, as forward motion is necessary to sustentation, the transverse balance is easily controlled at the wing tips. It would be the same with the stability of a ship having little or no transverse metacentric height if she were provided with a couple of long rigid levers projecting out from each side and a small hydroplane at the end of each lever. Such a device, however, would not serve to balance the ship any more than it does the bird when forward movement ceases. It is in this way that Mr. Curtis preserves the transverse balance of his hydro-aeroplane while on the surface of the water and for this reason also that he adds small air-chambers or pontoons to the small hydroplanes situated at the ends of the lower plane.

But the longitudinal stability of an aeroplane, unlike that of the ship, is of paramount importance and is the chief concern of the experienced aviator, for by it and within a small range he has to maintain the efficiency of his angle of incidence. Aviators are therefore more concerned with the fear of deadening the flight, by changing the angle of incidence enough to permit the machine to come down either vertically or tail first, than they are with coming down at a sharp angle either head first or sideways.

I hope that many more naval architects will be able to devote sufficient time to aviation to follow Mr. McEntee's example, and to still further illuminate the pages of these transactions next year with the principles of Naval architecture as applied to aviation.

Naval Constructor McEntee (Communicated):—With regard to Captain Chambers' remarks in connection with the relative importance of transverse and

longitudinal stability, it was not the intention in the paper to take the ground that at the present stage of development, the transverse stability is the more important. What the paper was intended to bring out is the fact that before the introduction of ailerons or warping wings, such as was the case when Langley conducted his experiments, that the longitudinal stability was greater than the transverse stability. Langley depended for transverse stability almost entirely on the dihedral angle. In other words he placed the center of gravity of the total weight a considerable distance below the center of buoyancy of the supporting surfaces. This naturally resulted in a reduction of the longitudinal stability because of the pendulum action resulting from the low placed center of gravity as referred to in the paper.

THE PRESIDENT:—We will now close the meeting, with the thanks of the Society to Messrs. Roberts and McEntee for the papers which they have presented to us.

The President requested that the members of the Council convene for a meeting, after which the meeting was adjourned.

Deaths, 1911.

William H. Allderdice.
Frederick C. Bowers.
Alexander E. Brown.
Randall T. Dickinson.
Jarvis B. Edson.
James J. Killilea.
Douglass G. Moore.
William Rowland.
Horace T. Sloan, Jr.
A. Cary Smith.
Calvin B. Orcutt.
Walter L. Pierce.
Howard Wood.

PLATES

To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

TABLE Nº I.

TABLE OF MODEL DIMENSIONS AND COEFFICIENTS

SERIES Nº 29.

D = 2250 LBS. L = 20·0 FT. B = 2·795 FT. H = 1·118 FT. $\frac{36}{35}\frac{D}{\left[\frac{L}{100}\right]^3} = 12{\cdot}915$ $\frac{B}{H} = 2{\cdot}50$ $l = {\cdot}6000$ $m = {\cdot}9600$

VARIABLES.

MODEL Nº	SECTIONAL AREAS.				WATER LINES.					
	BOW		STERN		BOW			STERN		
	DESIGNATION	t	DESIGNATION	t	DESIGNATION	p	t	DESIGNATION	p	t
1092	d	1·271	d	1·333	1	·5500	0	1	·6000	·8000
1093	c	·953	c	1·000	1	"	"	1	"	"
1094	b	·636	b	·667	1	"	"	1	"	"
1095	a	·317	a	·333	1	"	"	1	"	"
1096	d	1·271	d	1·333	2	·6000	·667	2	·6500	1·4400
1097	c	·953	c	1·000	2	"	"	2	"	"
1098	b	·636	b	·667	2	"	"	2	"	"
1099	a	·317	a	·333	2	"	"	2	"	"
1100	d	1·271	d	1·333	3	·6500	1·333	3	·7000	2·1400
1101	c	·953	c	1·000	3	"	"	3	"	"
1102	b	·636	b	·667	3	"	"	3	"	"
1103	a	·317	a	·333	3	"	"	3	"	"
1104	d	1·271	d	1·333	4	·7000	2·000	4	·7500	3·0000
1105	c	·953	c	1·000	4	"	"	4	"	"
1106	b	·636	b	·667	4	"	"	4	"	"
1107	a	·317	a	·333	4	"	"	4	"	"

SERIES Nº 32.

D = 2250 LBS. L = 20·0 FT. B = 2·708 FT. H = 1·083 FT. $\frac{36}{35}\frac{D}{\left[\frac{L}{100}\right]^3} = 12{\cdot}915$ $\frac{B}{H} = 2{\cdot}50$ $l = {\cdot}6400$ $m = {\cdot}9600$

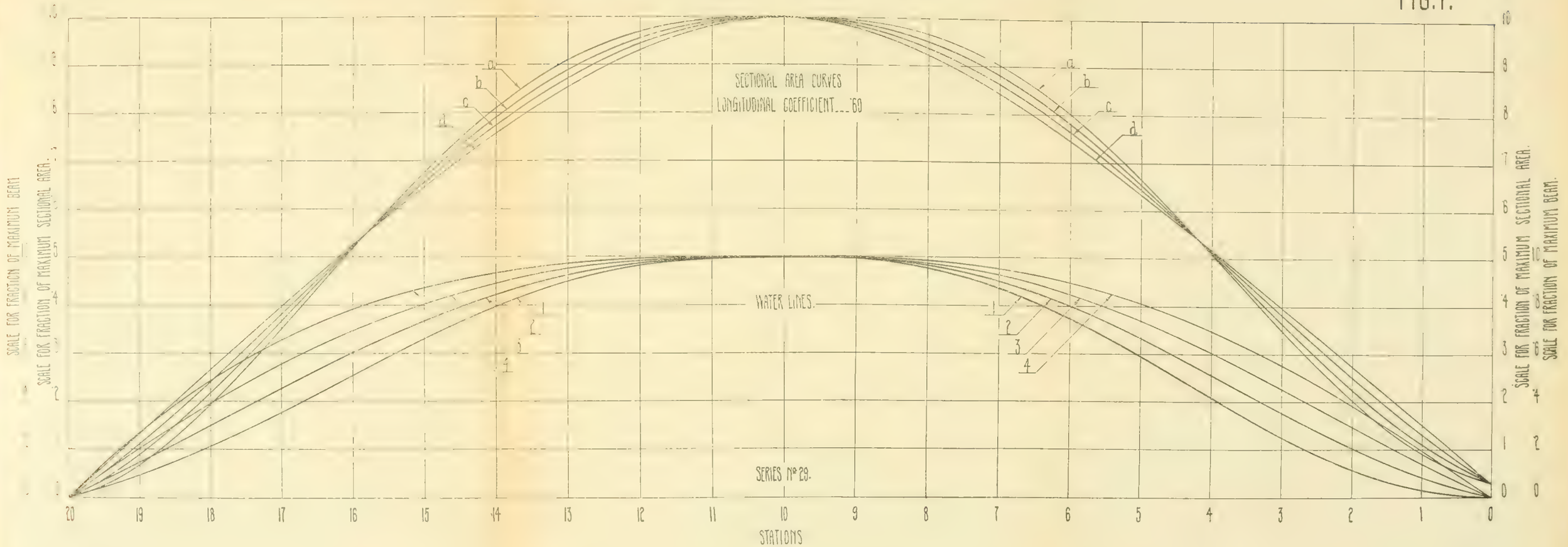
VARIABLES.

MODEL Nº	SECTIONAL AREAS				WATER LINES.					
	BOW		STERN		BOW			STERN		
	DESIGNATION	t	DESIGNATION	t	DESIGNATION	p	t	DESIGNATION	p	t
1191	d	1·750	d	1·800	1	·5500	0	1	·6500	1·440
1192	c	1·350	c	1·400	1	"	"	1	"	"
1193	b	·950	b	1·000	1	"	"	1	"	"
1194	a	·550	a	·600	1	"	"	1	"	"
1195	d	1·750	d	1·800	2	·6000	·667	2	·7000	2·140
1196	c	1·350	c	1·400	2	"	"	2	"	"
1197	b	·950	b	1·000	2	"	"	2	"	"
1198	a	·550	a	·600	2	"	"	2	"	"
1199	d	1·750	d	1·800	3	·6500	1·333	3	·7500	3·000
1200	c	1·350	c	1·400	3	"	"	3	"	"
1201	b	·950	b	1·000	3	"	"	3	"	"
1202	a	·550	a	·600	3	"	"	3	"	"
1203	d	1·750	d	1·800	4	·7000	2·000	4	·8000	4·000
1204	c	1·350	c	1·400	4	"	"	4	"	"
1205	b	·950	b	1·000	4	"	"	4	"	"
1206	a	·550	a	·600	4	"	"	4	"	"

To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

CURVES OF WATER LINES AND SECTIONAL AREAS FOR SERIES Nos. 29 AND 32.

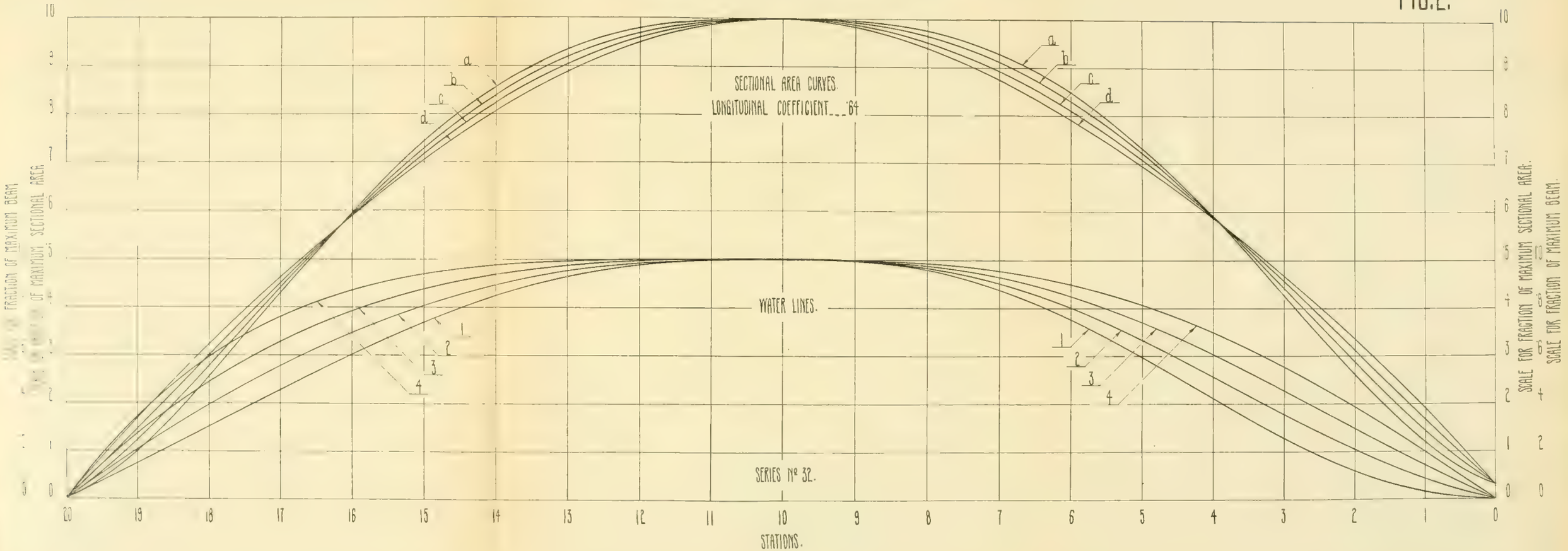
FIG. 1.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

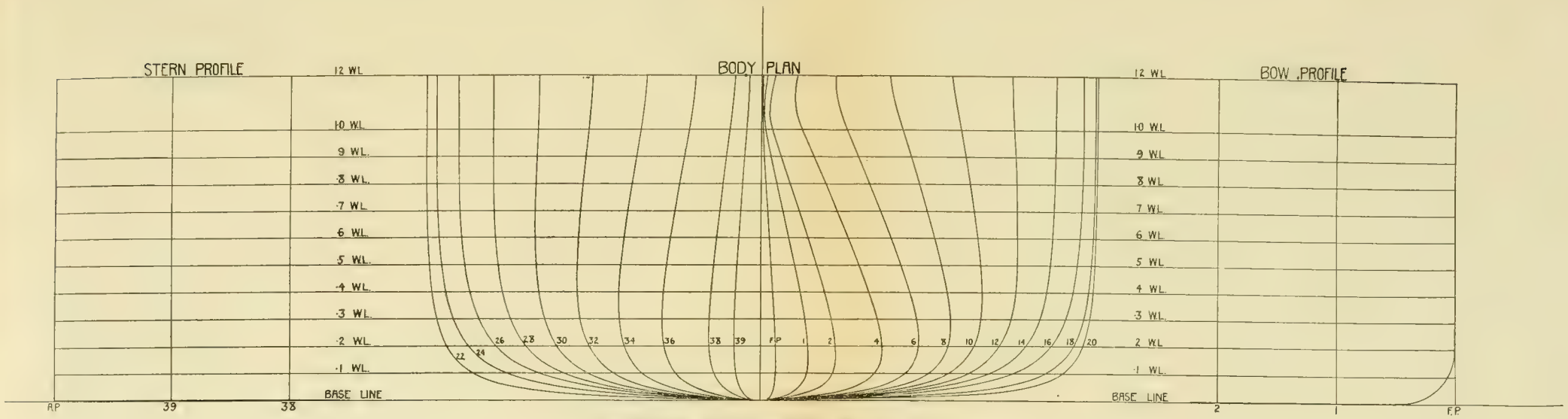
CURVES OF WATER LINES AND SECTIONAL AREAS FOR SERIES Nos. 29 AND 32.

FIG. 2.



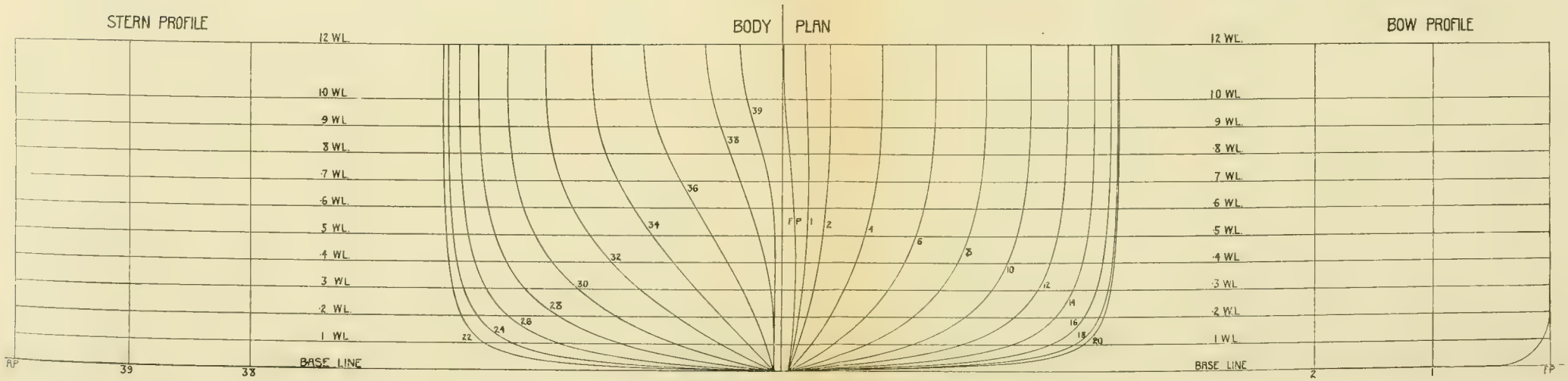
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

Fig. 3.



BODY PLAN AND BOW AND STERN PROFILES
OF
MODEL Nº 1092

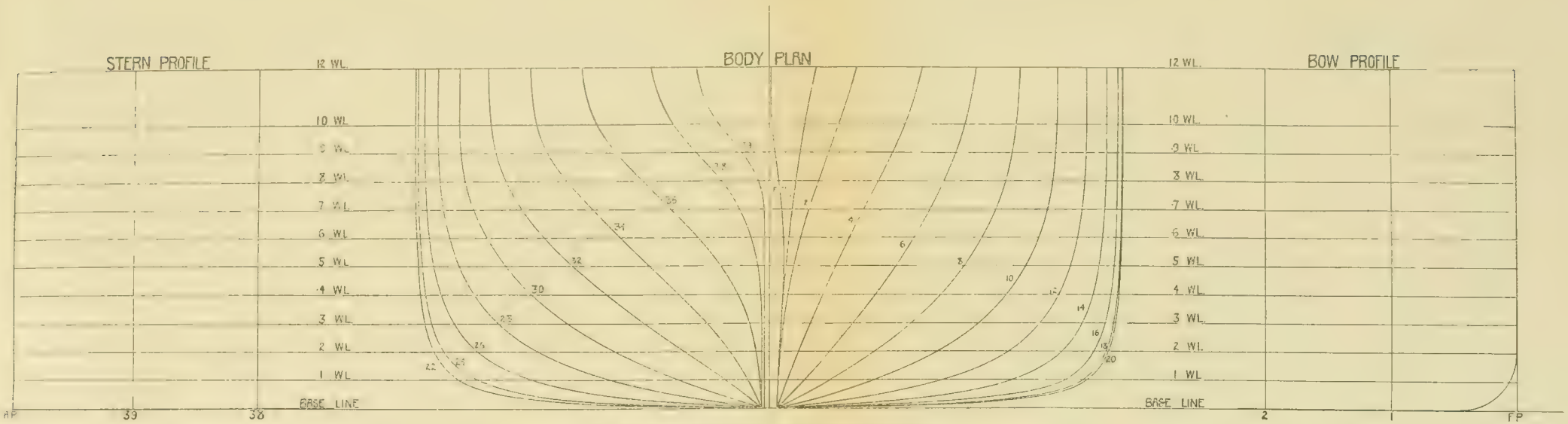
Fig. 4



BODY PLAN AND BOW AND STERN PROFILES
OF
MODEL Nº 1102

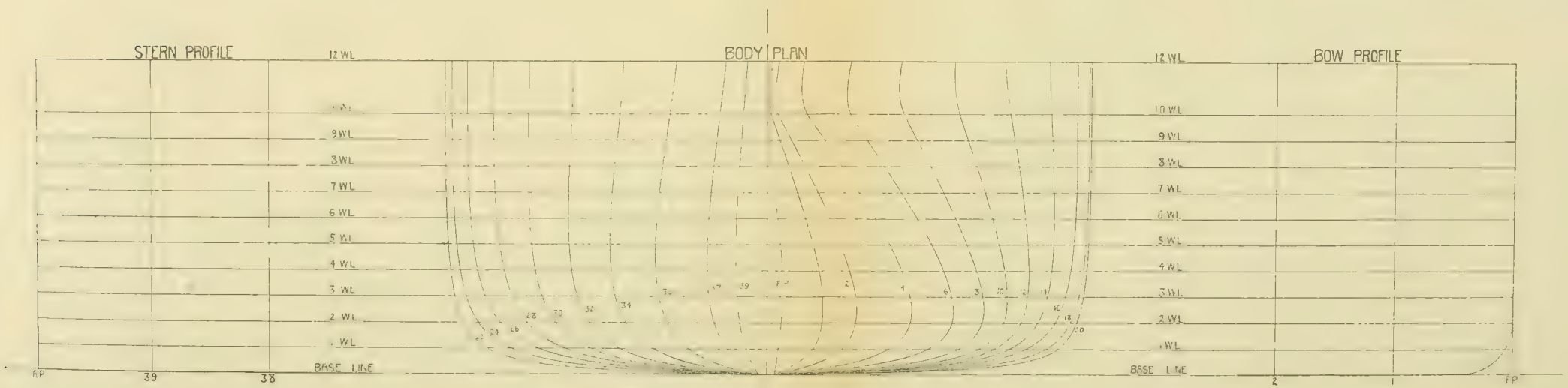
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

Fig. 5.



BODY PLAN AND BOW AND STERN PROFILES
OF
MODEL Nº 1107

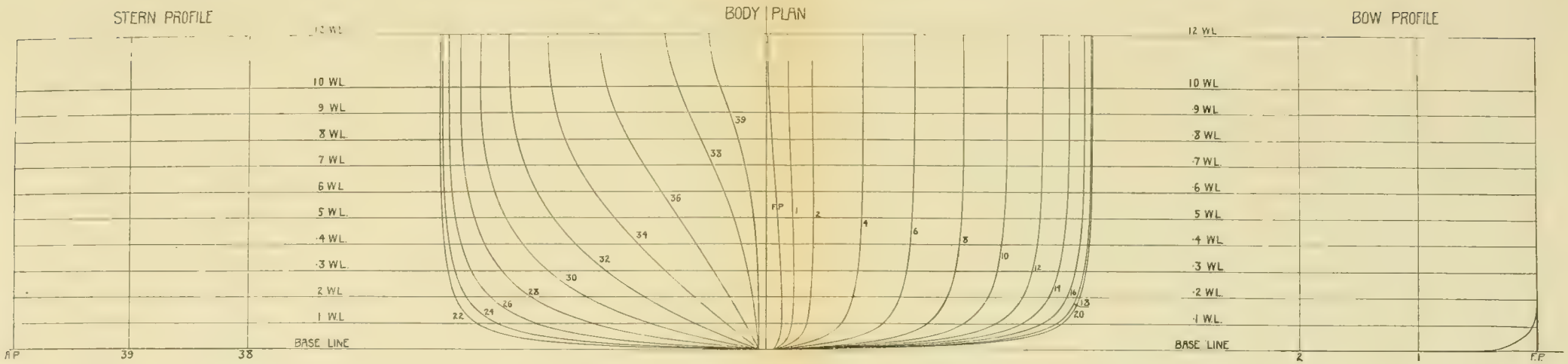
Fig. 6.



BODY PLAN AND BOW AND STERN PROFILES
OF
MODEL Nº 1191

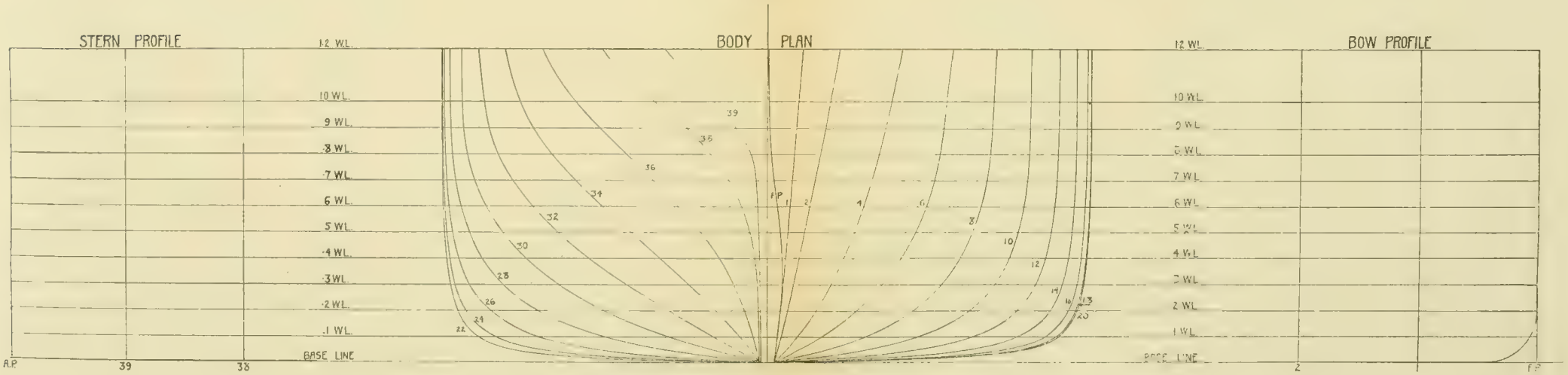
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 7



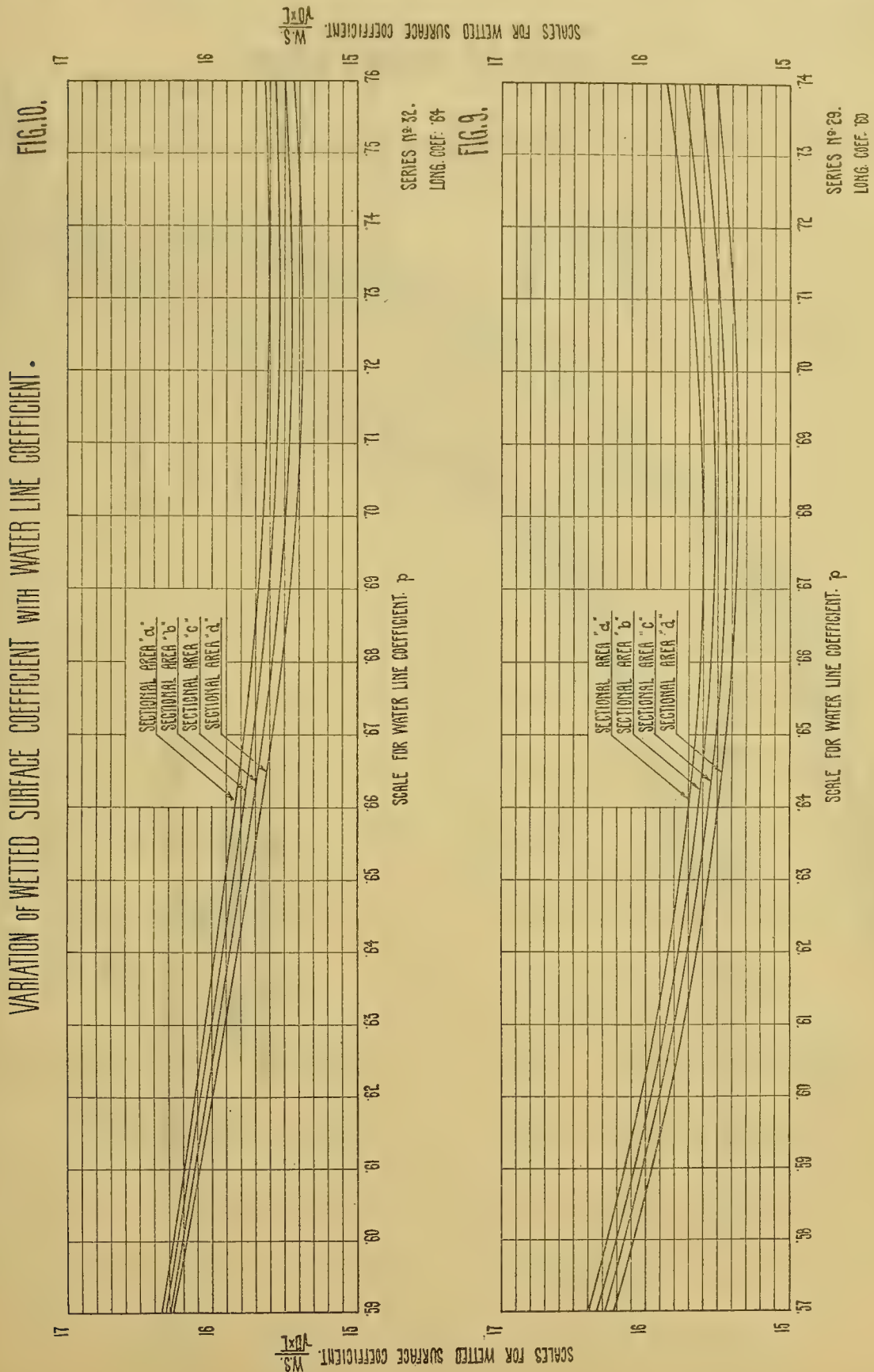
BODY PLAN AND BOW AND STERN PROFILES
OF
MODEL Nº 1201

FIG. 8.



BODY PLAN AND BOW AND STERN PROFILES
OF
MODEL Nº 1206

To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

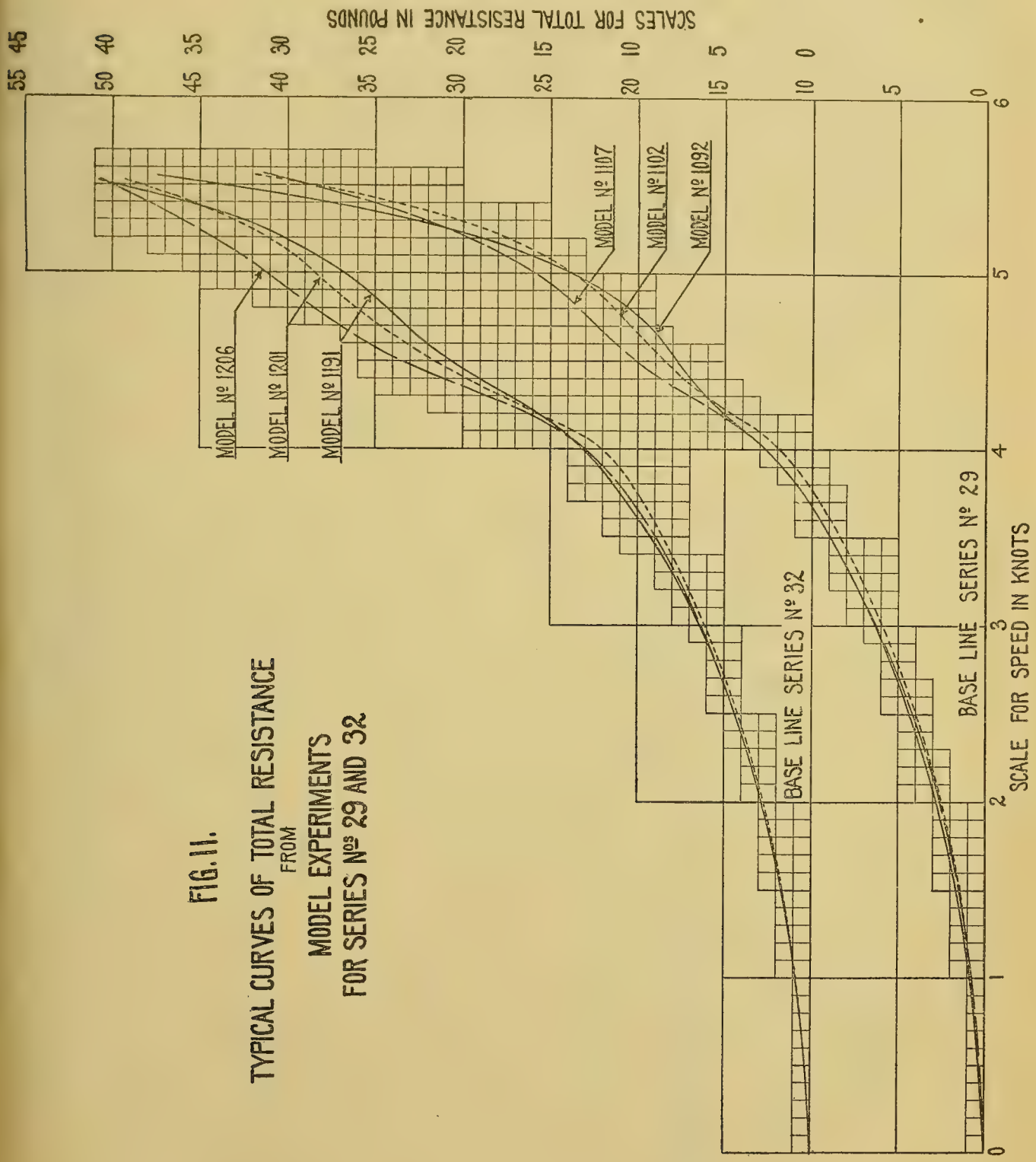
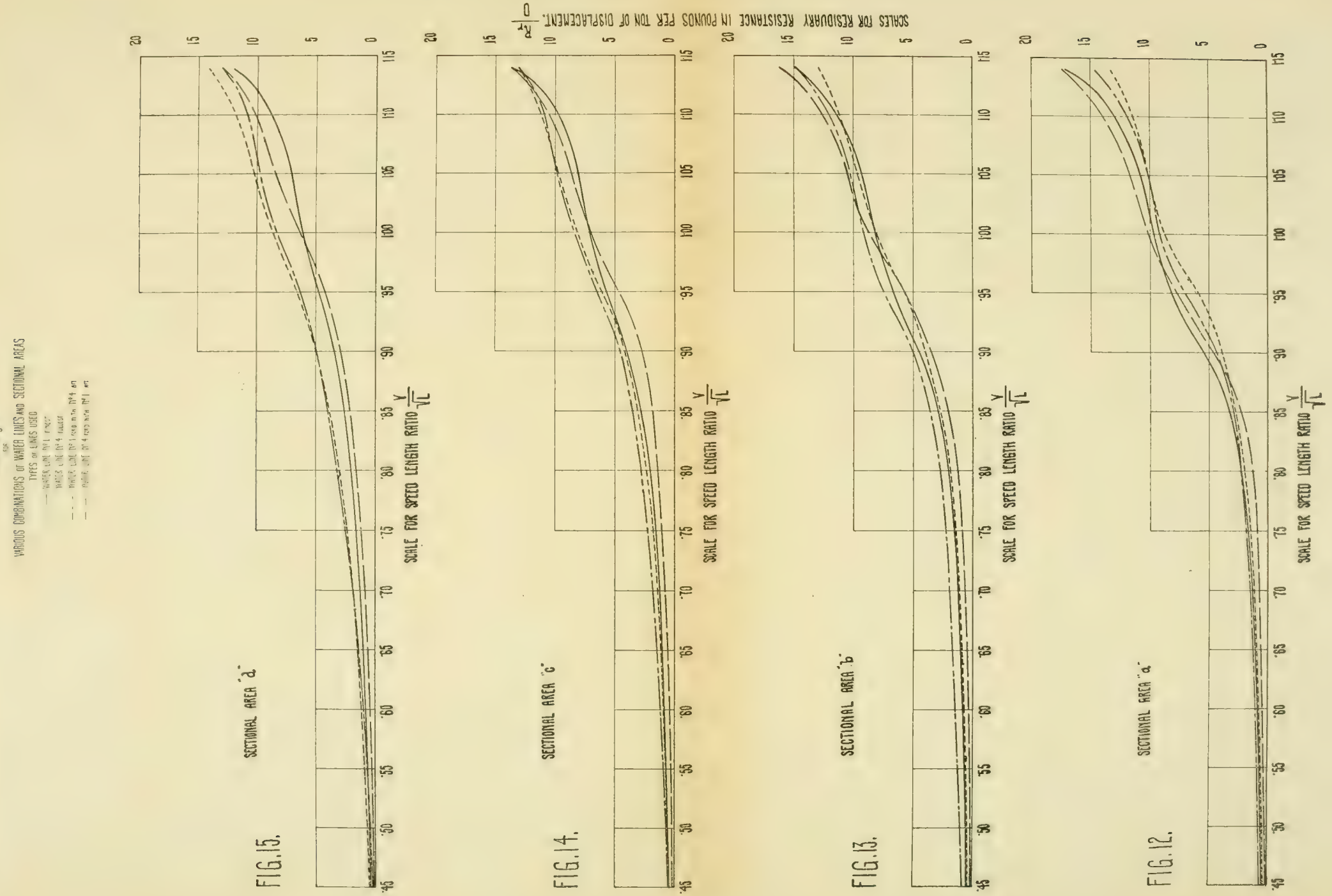
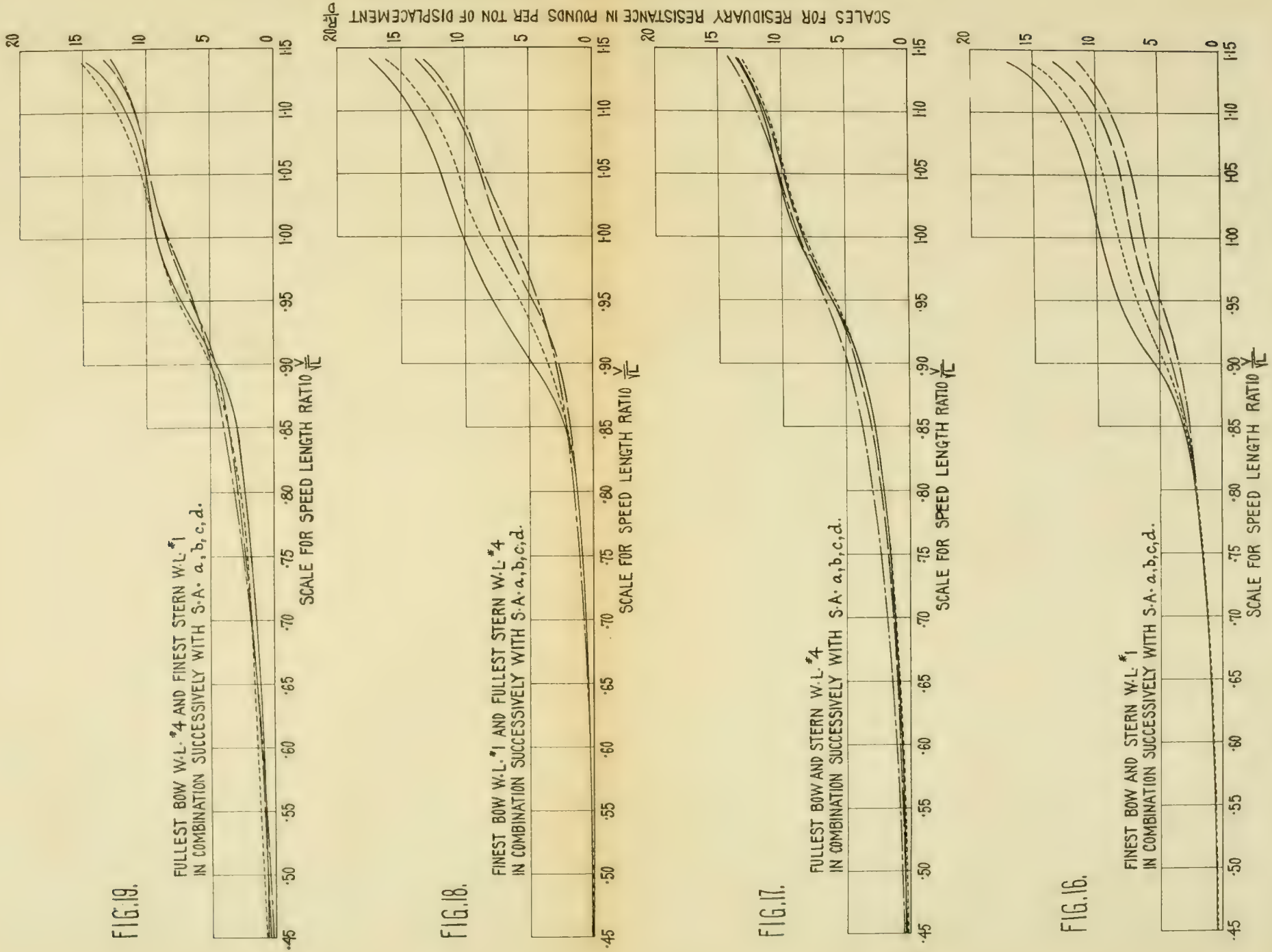


FIG. 11.
TYPICAL CURVES OF TOTAL RESISTANCE
FROM
MODEL EXPERIMENTS
FOR SERIES Nos 29 AND 32

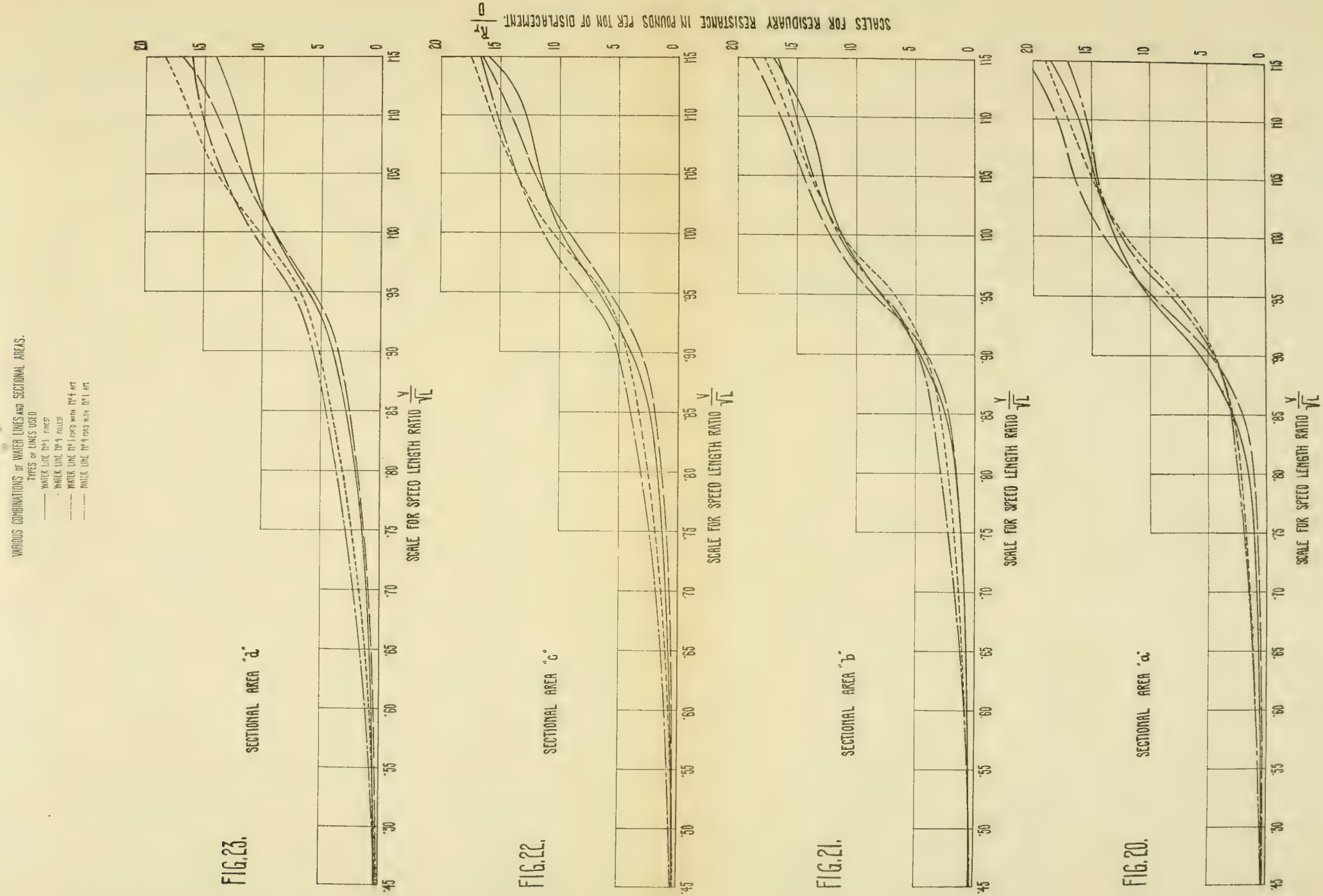
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

SERIES No 32.
CURVES OF $\frac{B}{D}$
FOR
VARIOUS COMBINATIONS OF WATER LINES AND SECTIONAL AREAS

TYPES OF LINES USED
S.A. a
S.A. b
S.A. c
S.A. d

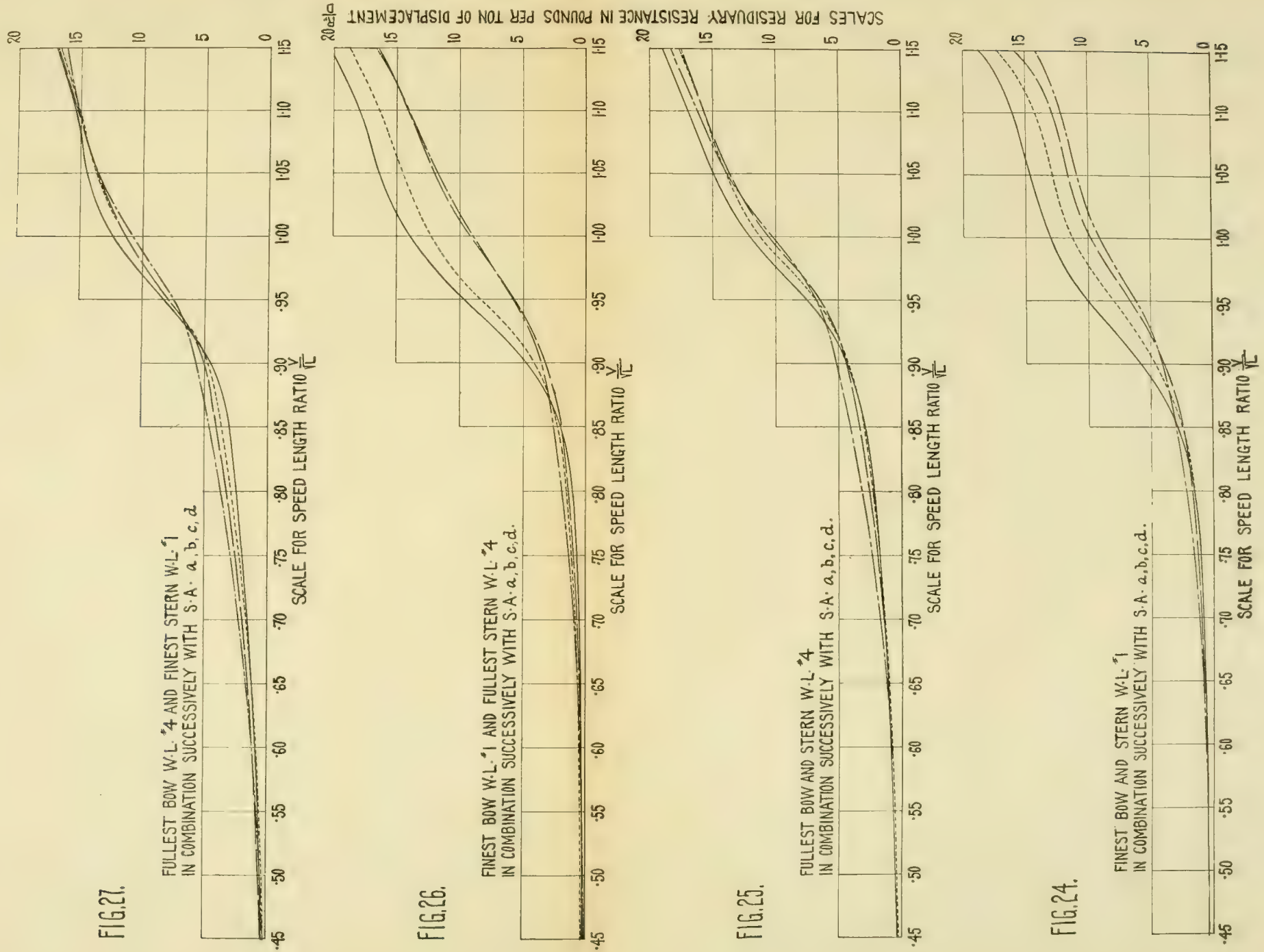


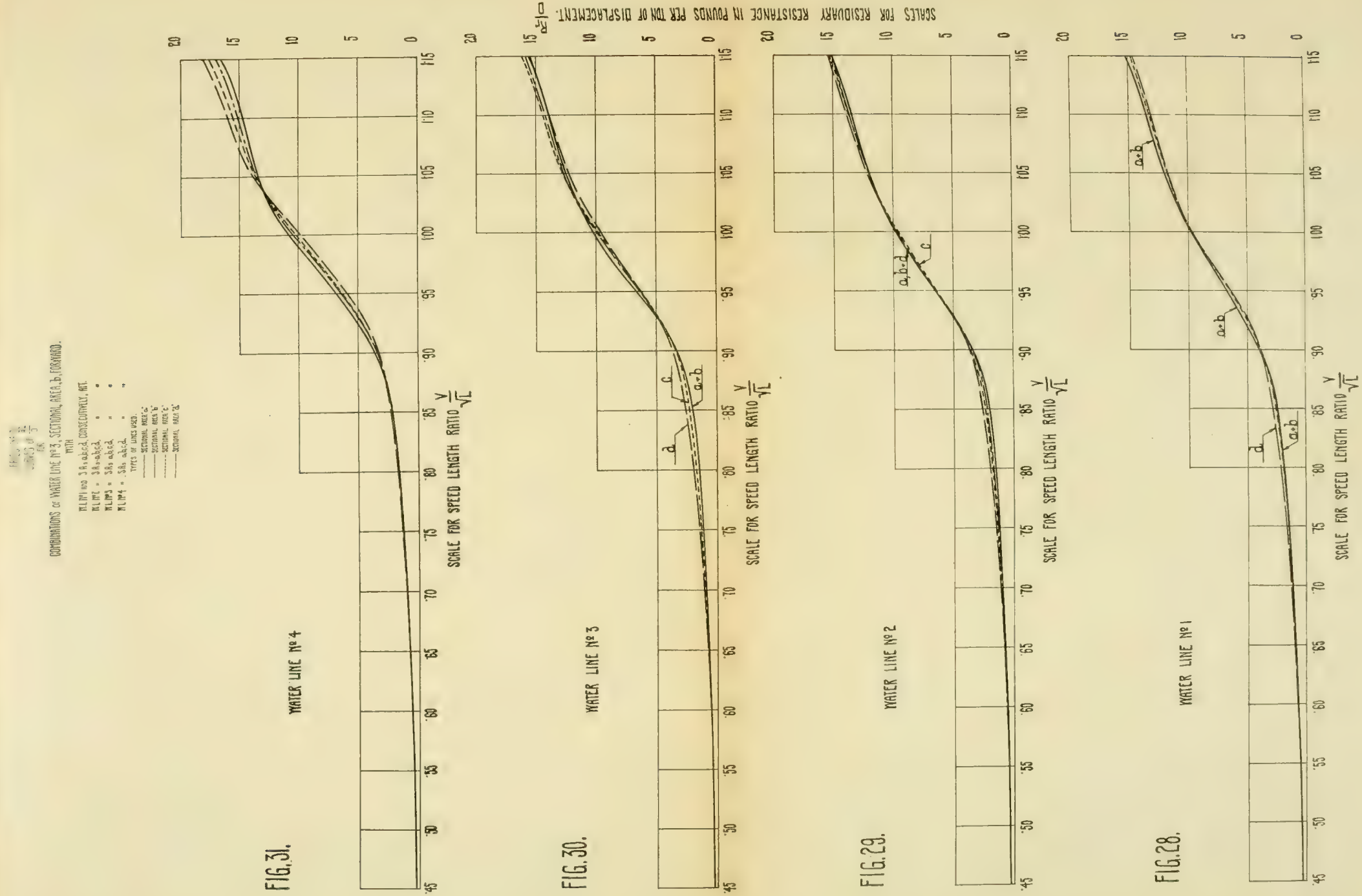
FIG. 27. FULLEST BOW W.L. #4 AND FINEST STERN W.L. #1 IN COMBINATION SUCCESSIVELY WITH S.A. a, b, c, d

FIG. 26. FINEST BOW W.L. #1 AND FULLEST STERN W.L. #4 IN COMBINATION SUCCESSIVELY WITH S.A. a, b, c, d.

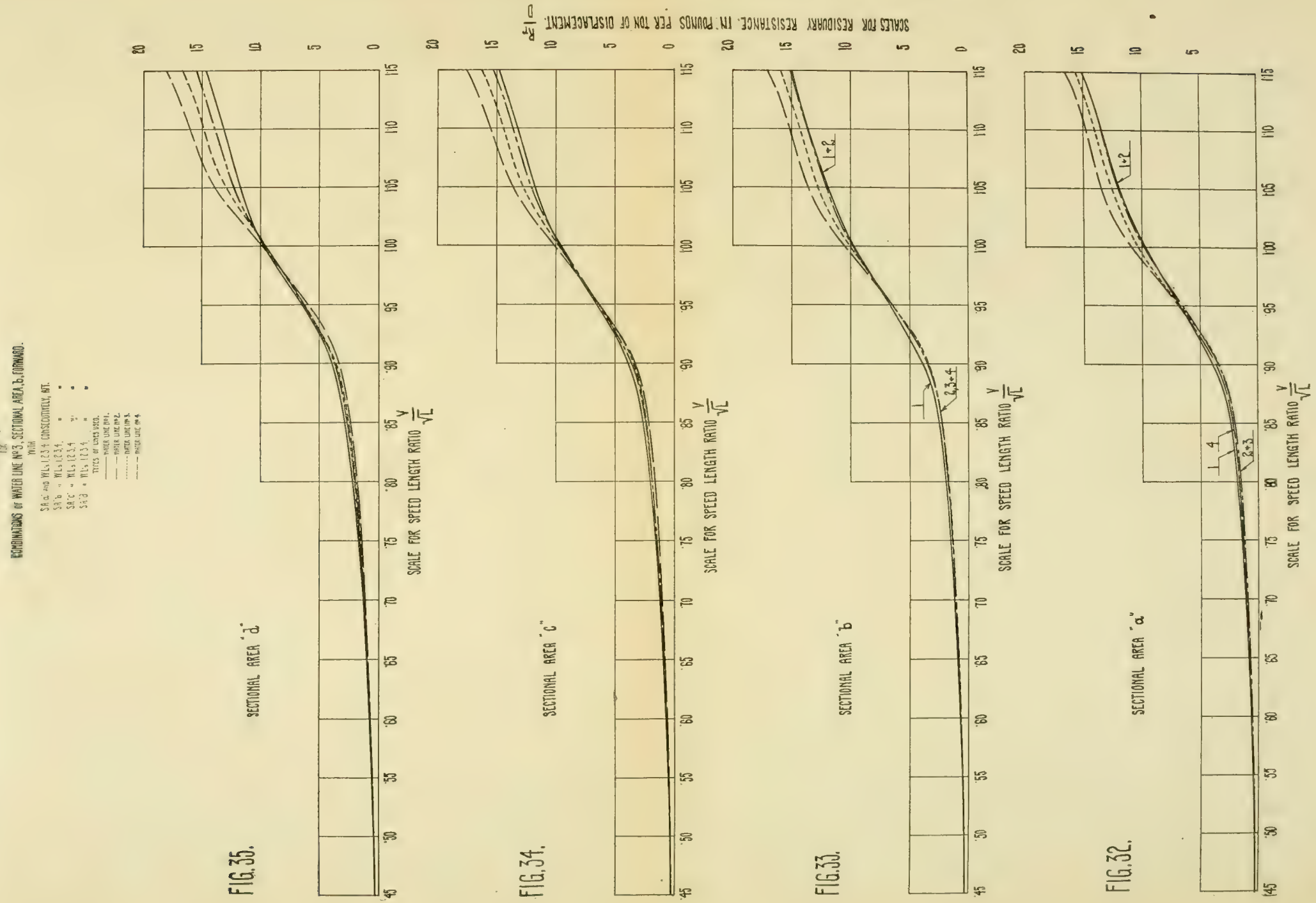
FIG. 25. FULLEST BOW AND STERN W.L. #4 IN COMBINATION SUCCESSIVELY WITH S.A. a, b, c, d.

FIG. 24. FINEST BOW AND STERN W.L. #1 IN COMBINATION SUCCESSIVELY WITH S.A. a, b, c, d.

To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.



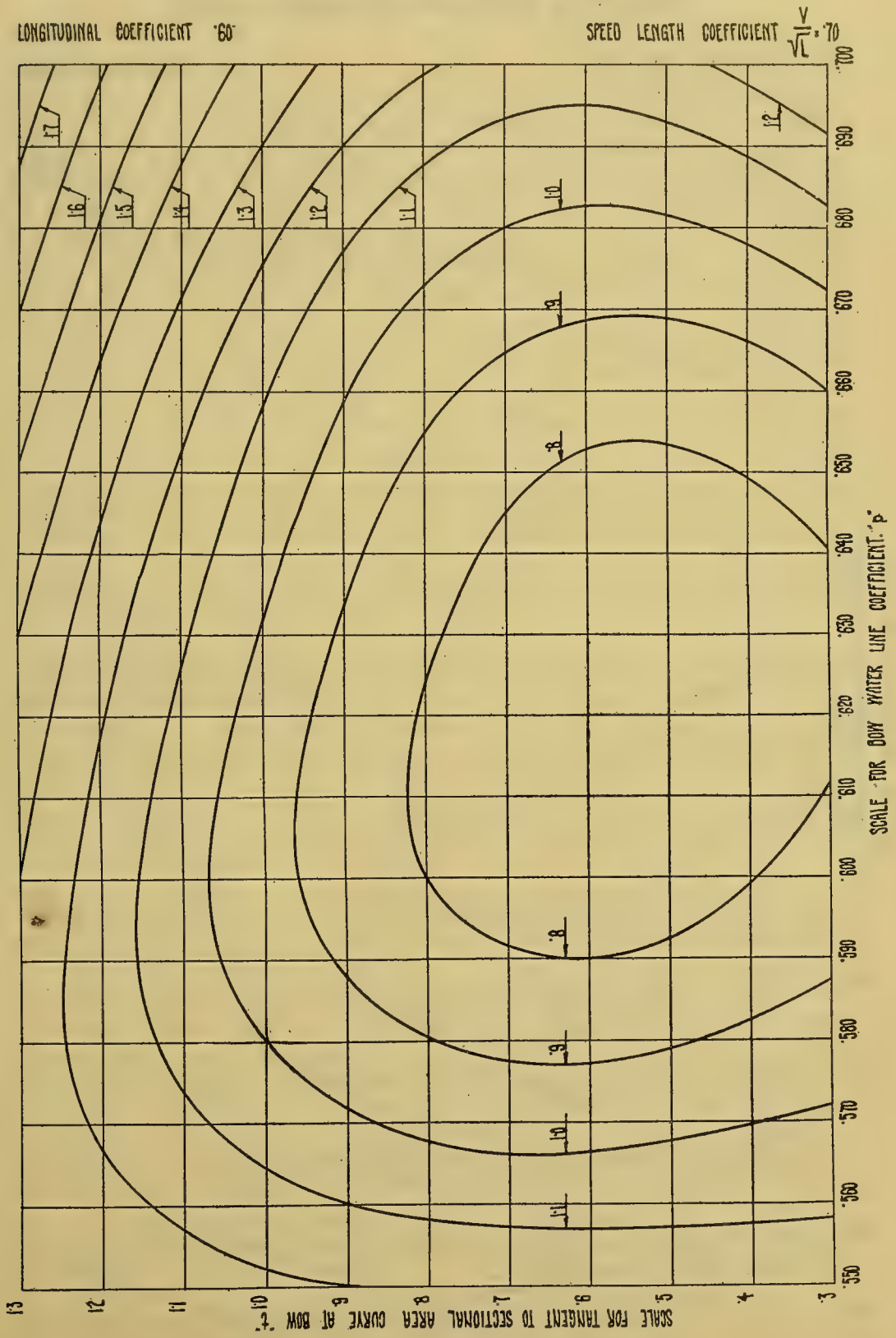
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 36.

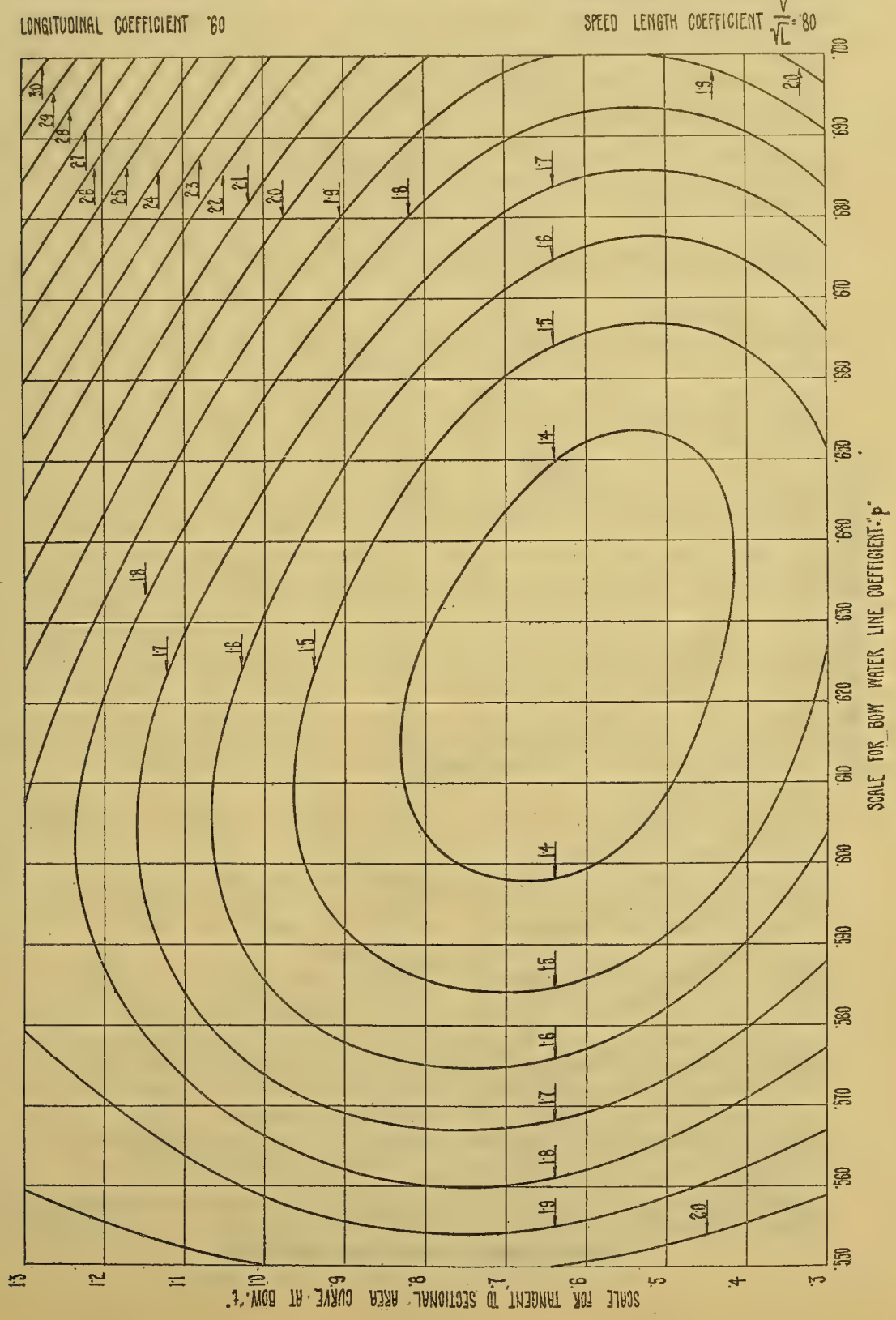
CONTOURS OF RESIDUARY RESISTANCE PER TON OF DISPLACEMENT.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 37.

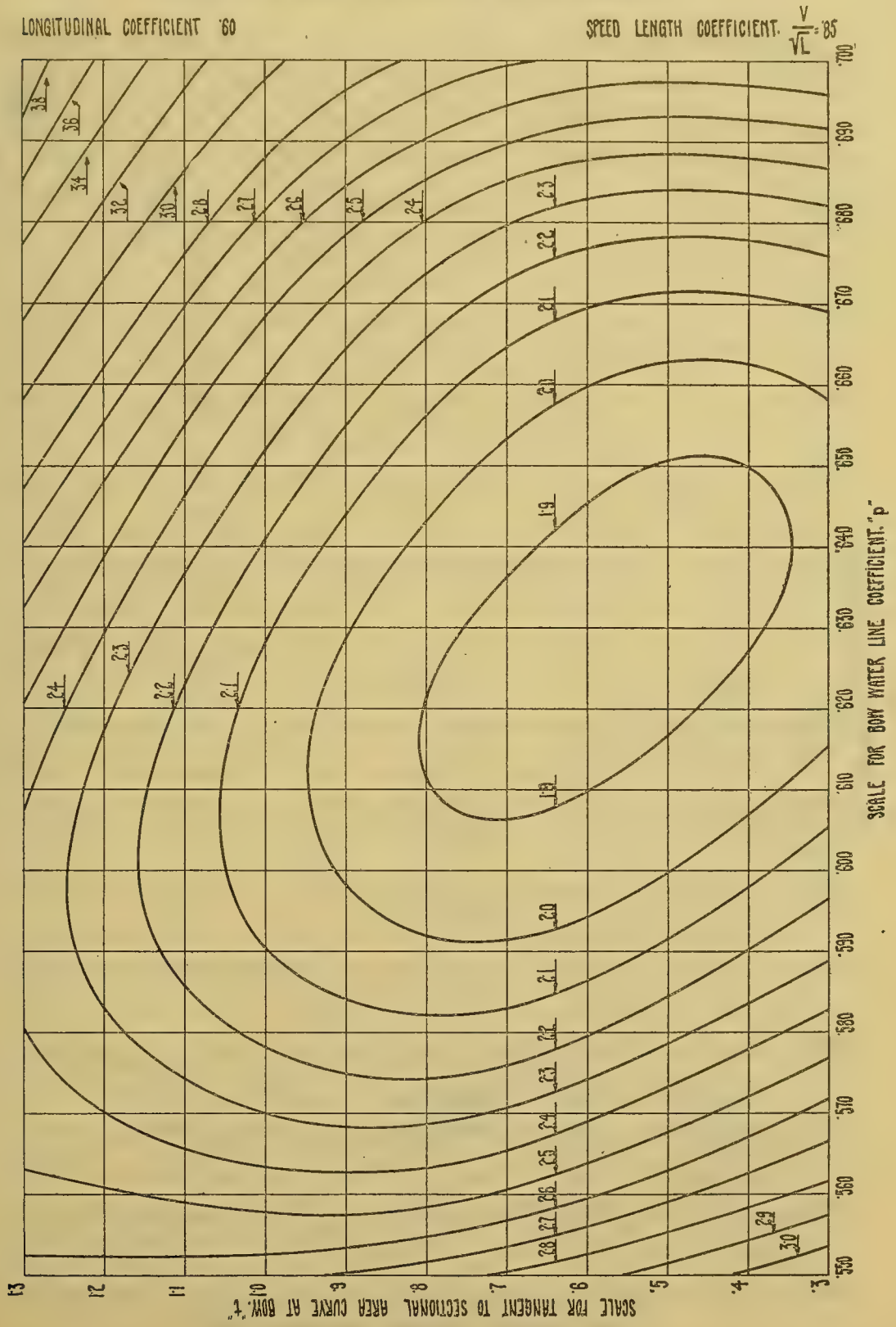
CONTOURS OF RESIDUARY RESISTANCE PER TON OF DISPLACEMENT.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 38.

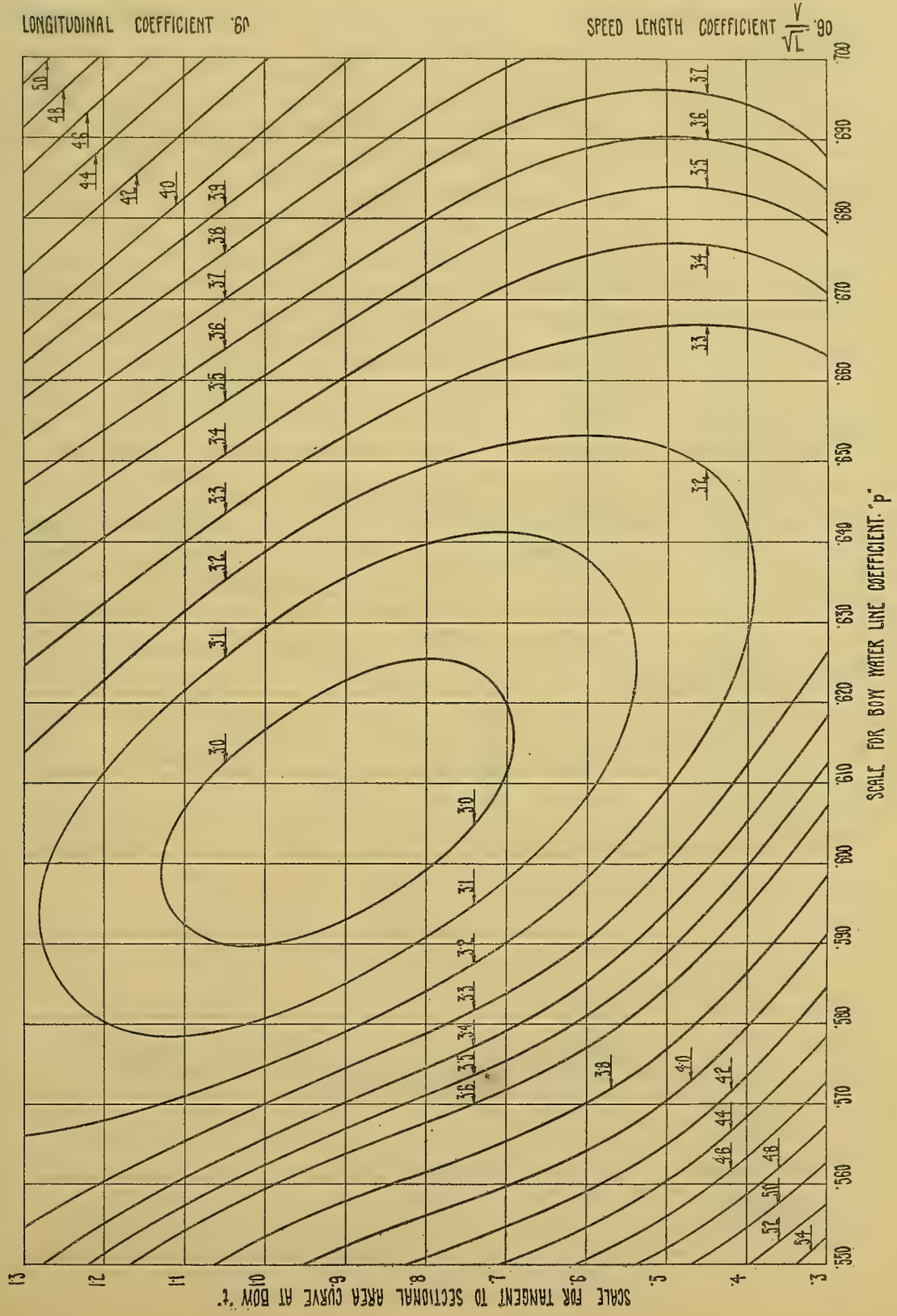
CONTOURS OF RESIDUARY RESISTANCE PER TON OF DISPLACEMENT.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 39.

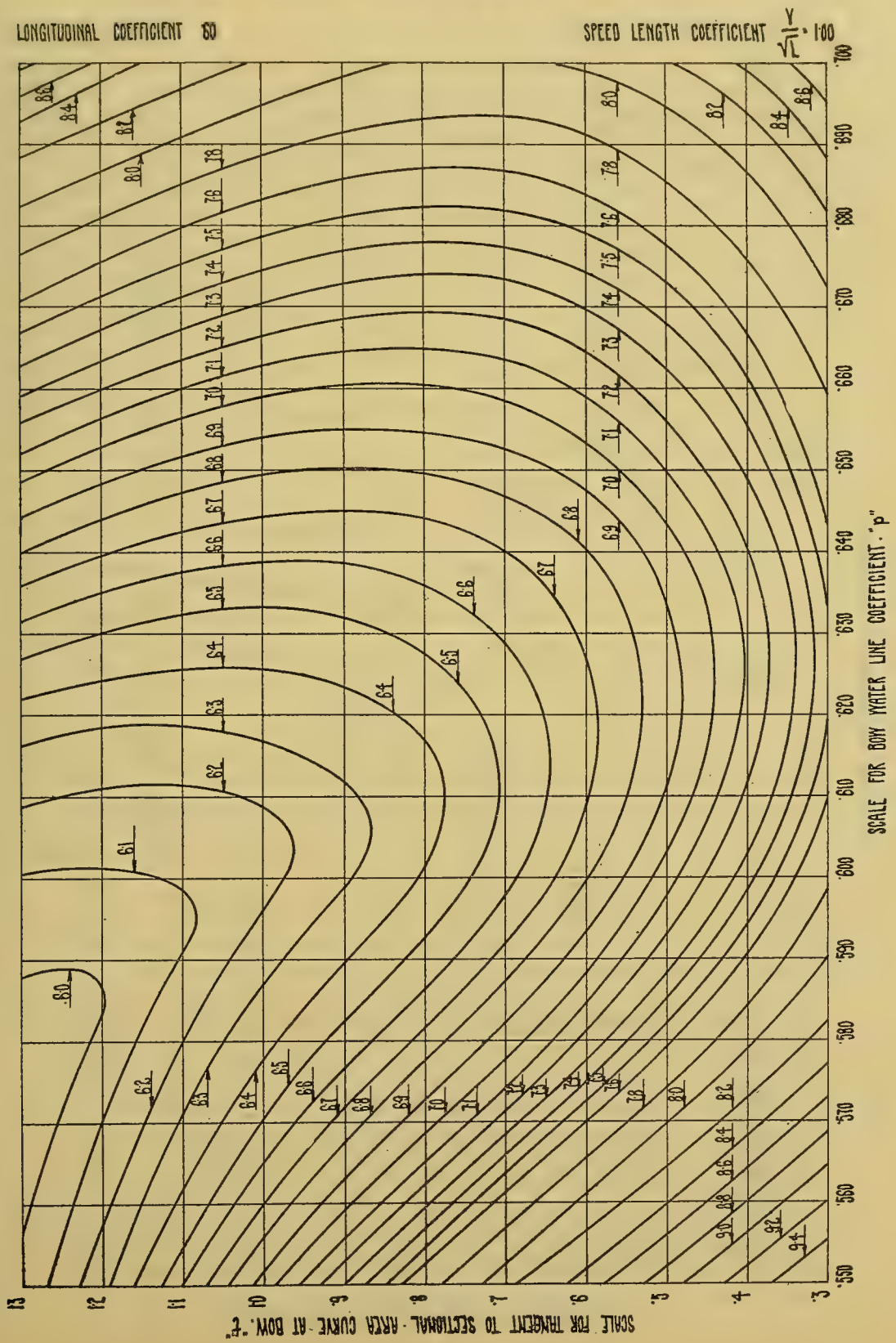
CONTOURS OF RESIDUARY RESISTANCE PER TON OF DISPLACEMENT.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 40.

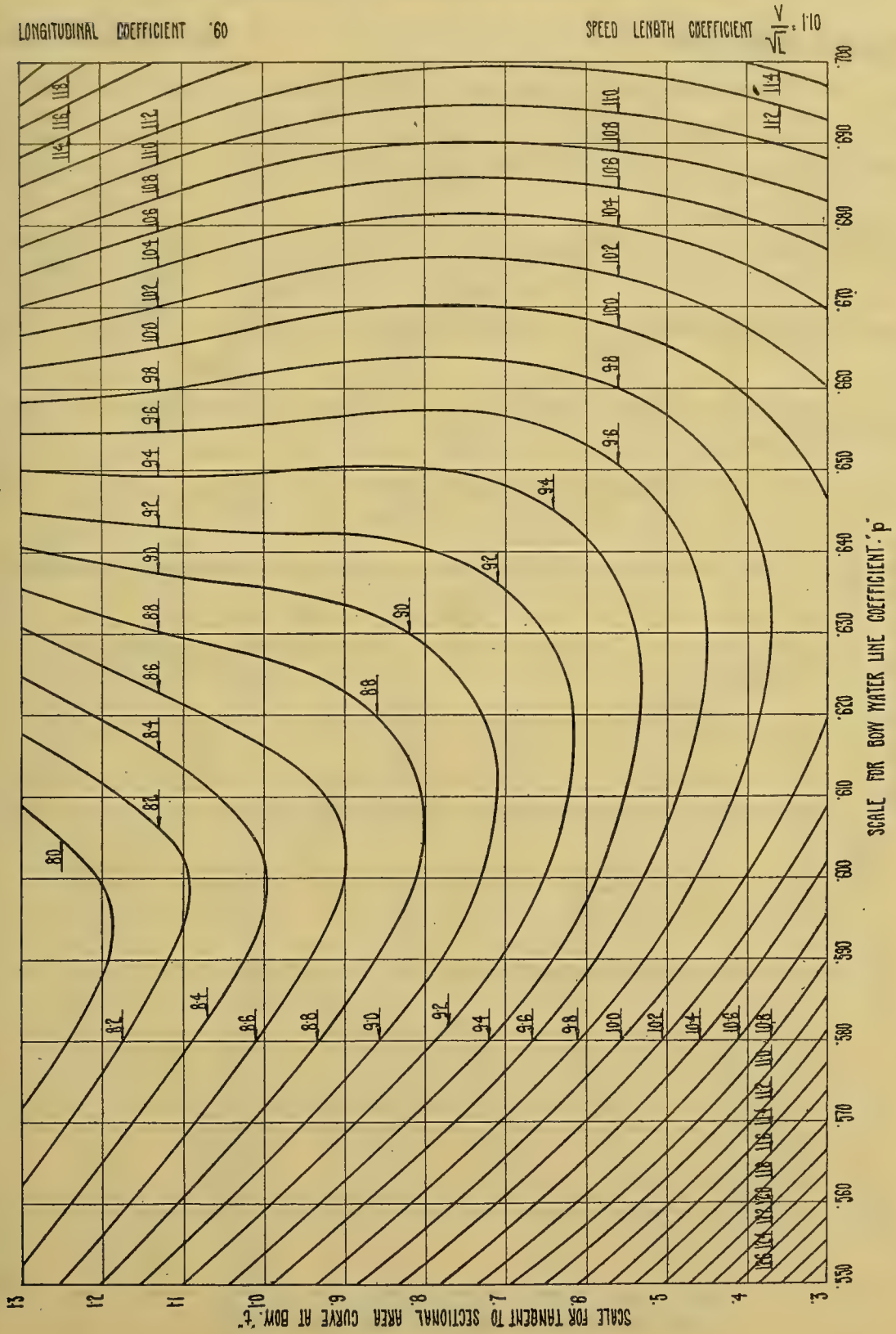
CONTOURS OF RESIDUARY RESISTANCE PER TON OF DISPLACEMENT.



To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 41.

CONTOURS OF RESIDUARY RESISTANCE PER TON OF DISPLACEMENT.



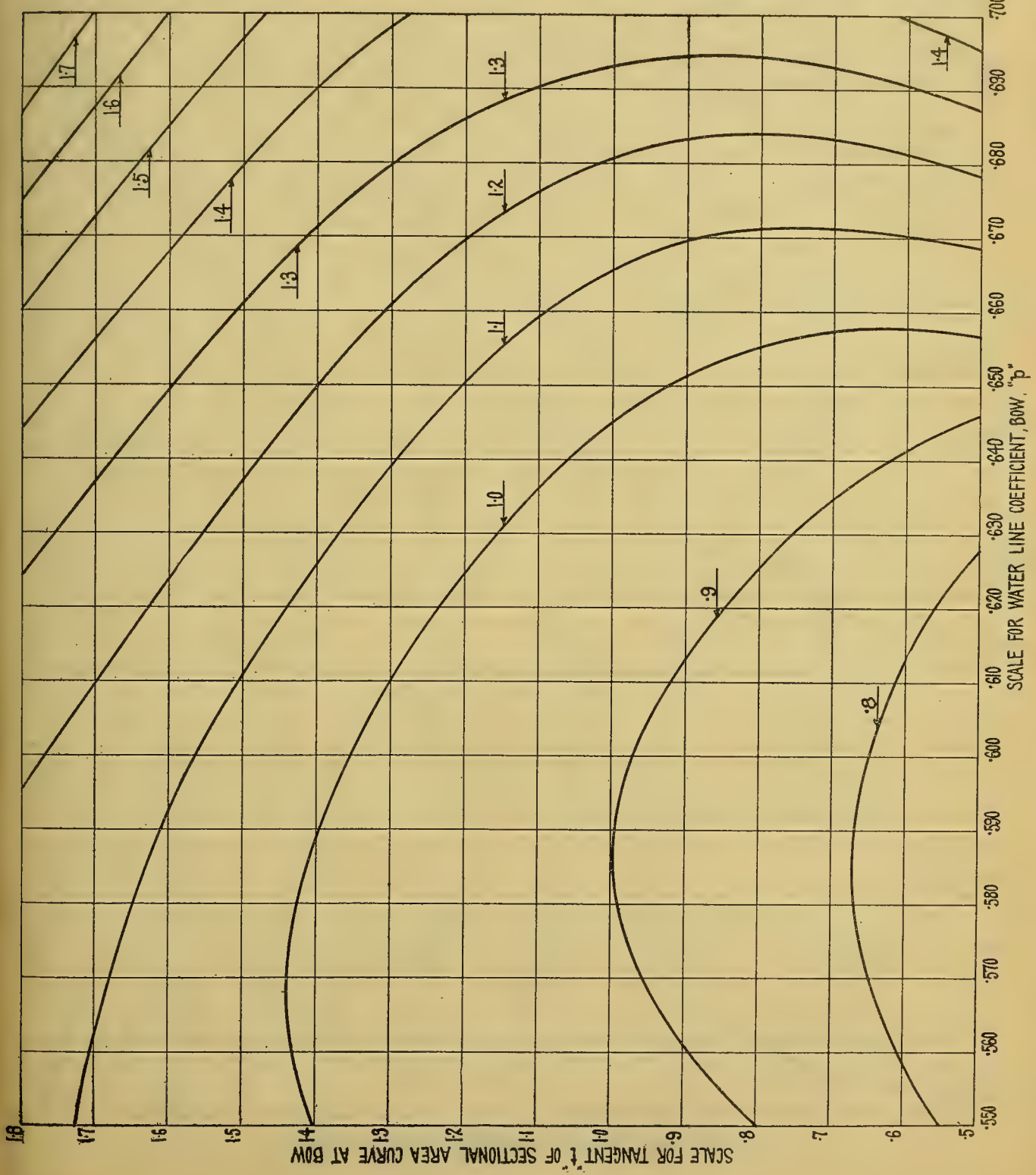
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 42.

CONTOURS OF RESIDUARY RESISTANCE IN POUNDS PER TON OF DISPLACEMENT

LONGITUDINAL COEFFICIENT ·64

SPEED LENGTH COEFFICIENT $\frac{V}{\sqrt{L}} = \cdot 70$



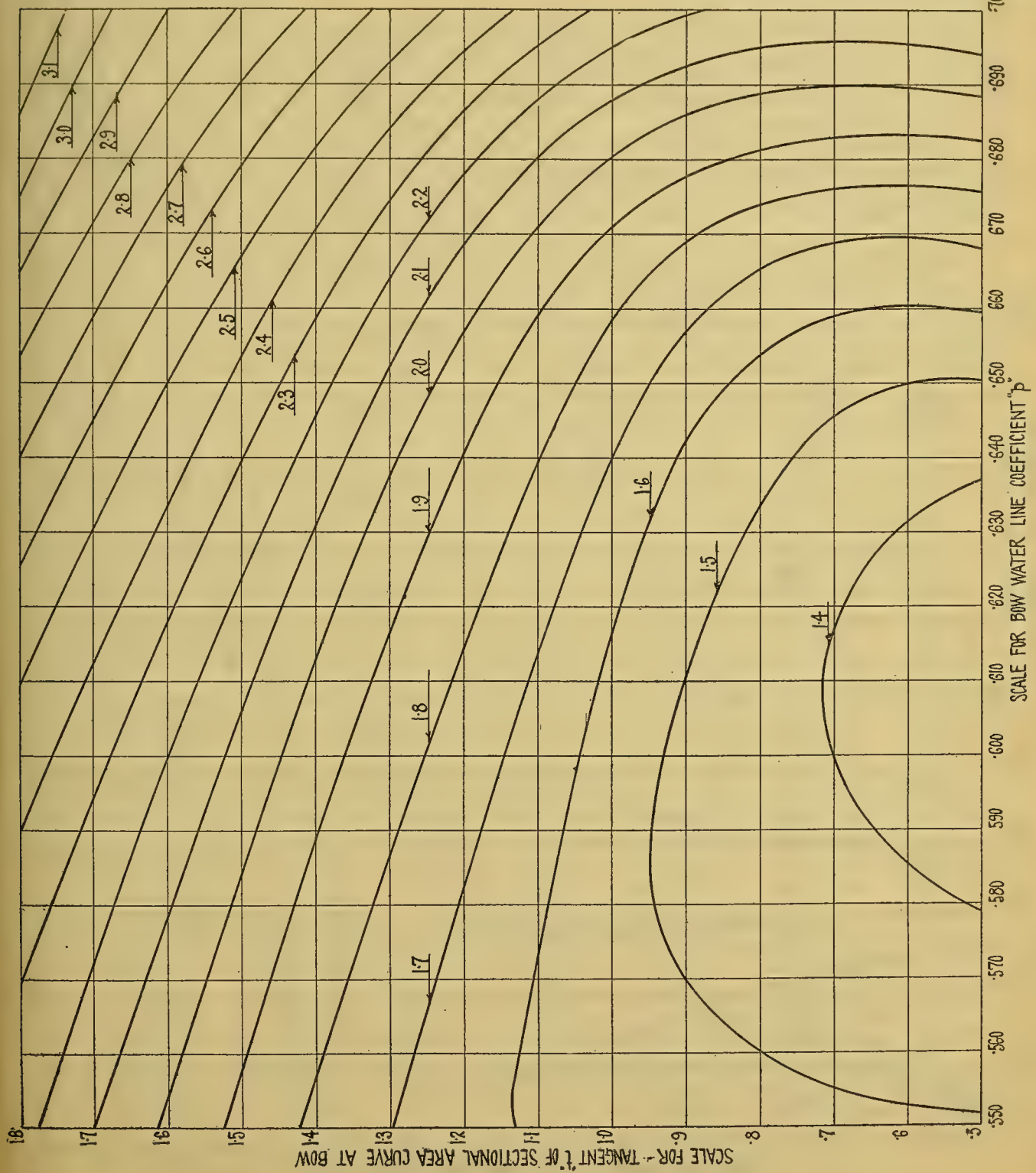
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 43.

CONTOURS OF RESIDUARY RESISTANCE IN POUNDS PER TON OF DISPLACEMENT

LONGITUDINAL COEFFICIENT ·64

SPEED LENGTH COEFFICIENT $\frac{V}{\sqrt{L}} = \cdot 80$



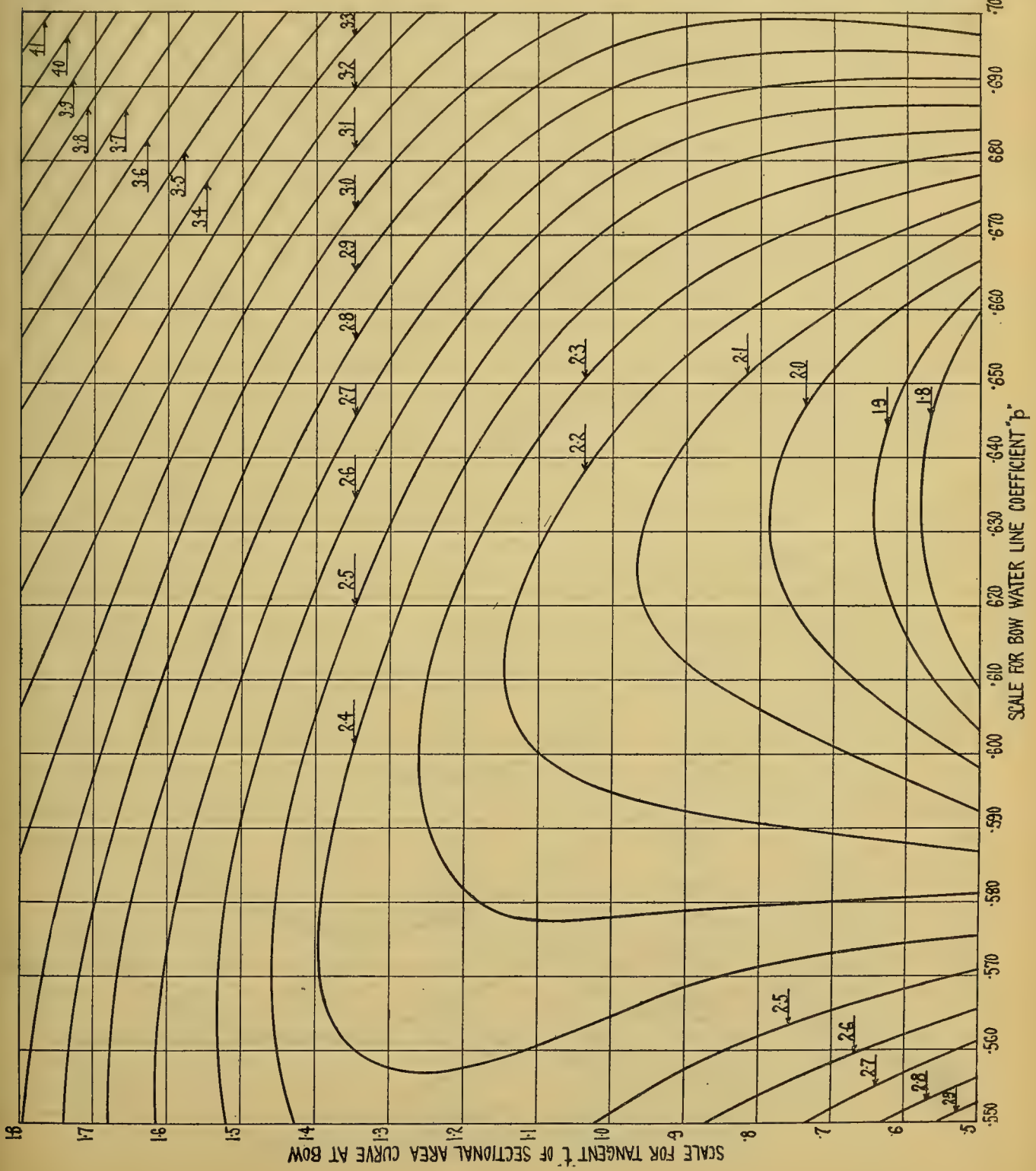
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 44.

CONTOURS OF RESIDUARY RESISTANCE IN POUNDS PER TON OF DISPLACEMENT

LONGITUDINAL COEFFICIENT ·64

SPEED LENGTH COEFFICIENT $\frac{V}{\sqrt{L}} = \cdot 85$



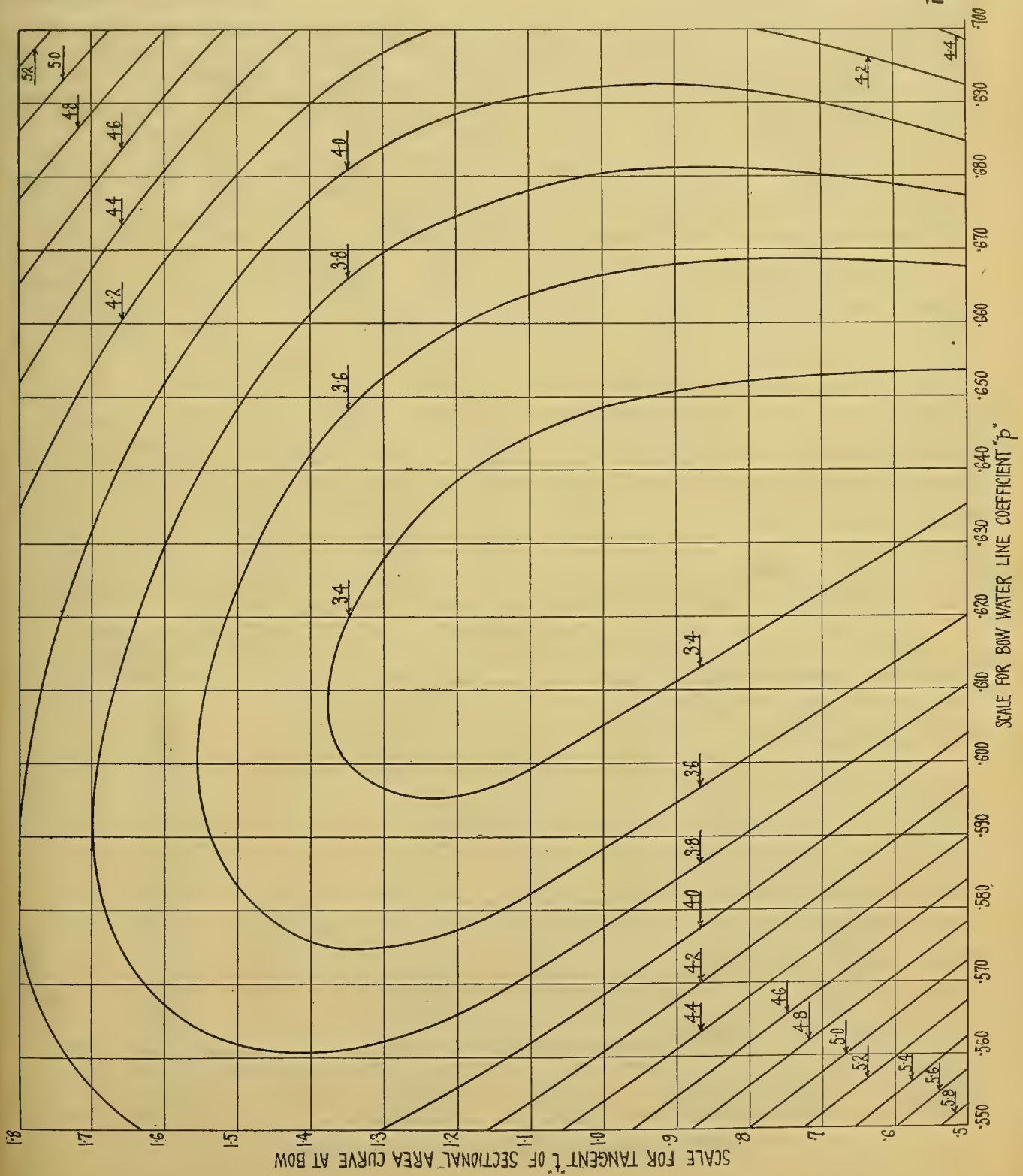
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 45.

CONTOURS OF RESIDUARY RESISTANCE IN POUNDS PER TON OF DISPLACEMENT

LONGITUDINAL COEFFICIENT ·64

SPEED LENGTH COEFFICIENT $\frac{V}{\sqrt{L}}$ = ·90



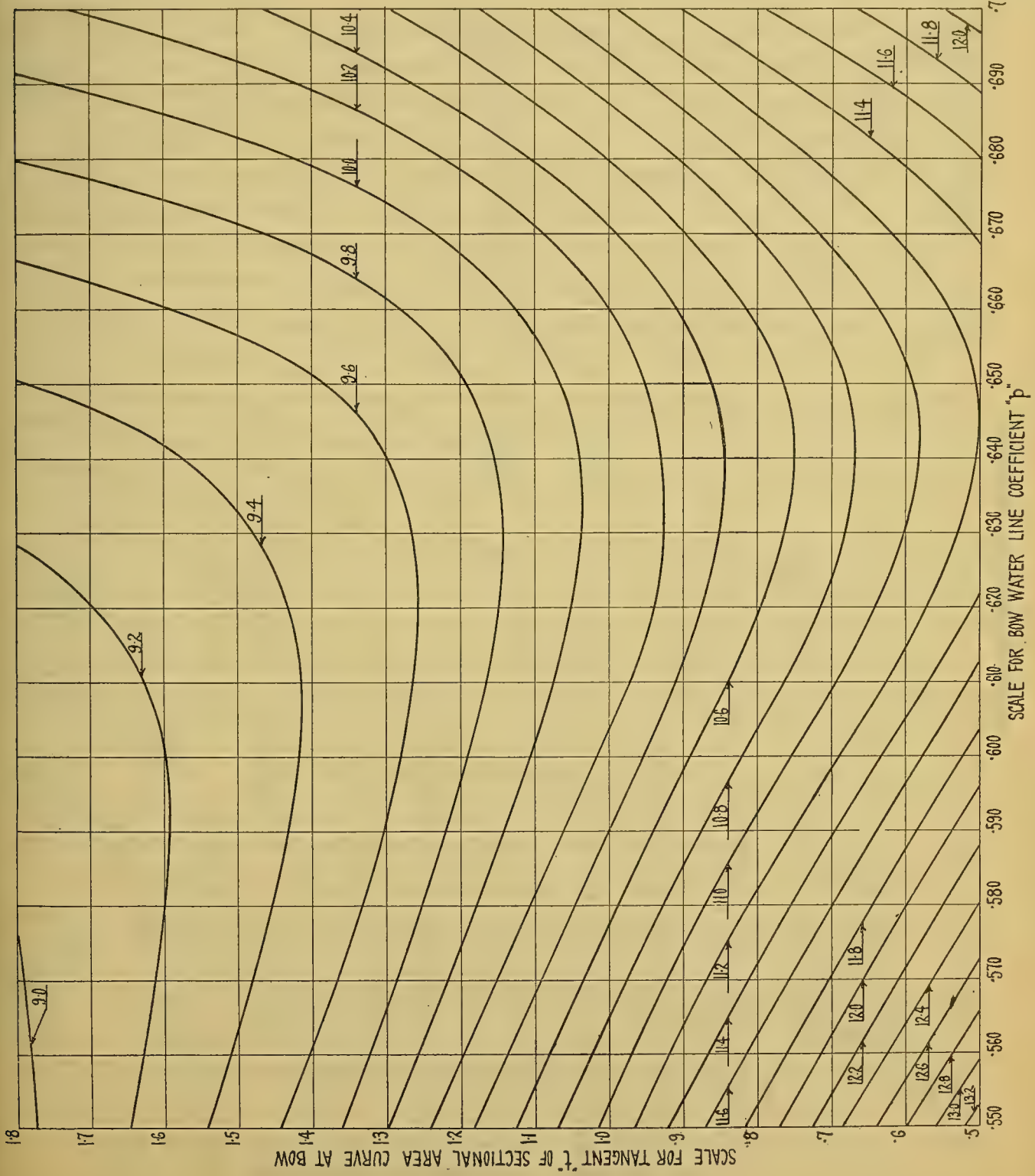
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 46.

CONTOURS OF RESIDUARY RESISTANCE IN POUNDS PER TON OF DISPLACEMENT

LONGITUDINAL COEFFICIENT ·64

SPEED LENGTH COEFFICIENT $\frac{V}{\sqrt{L}} = 1{\cdot}00$



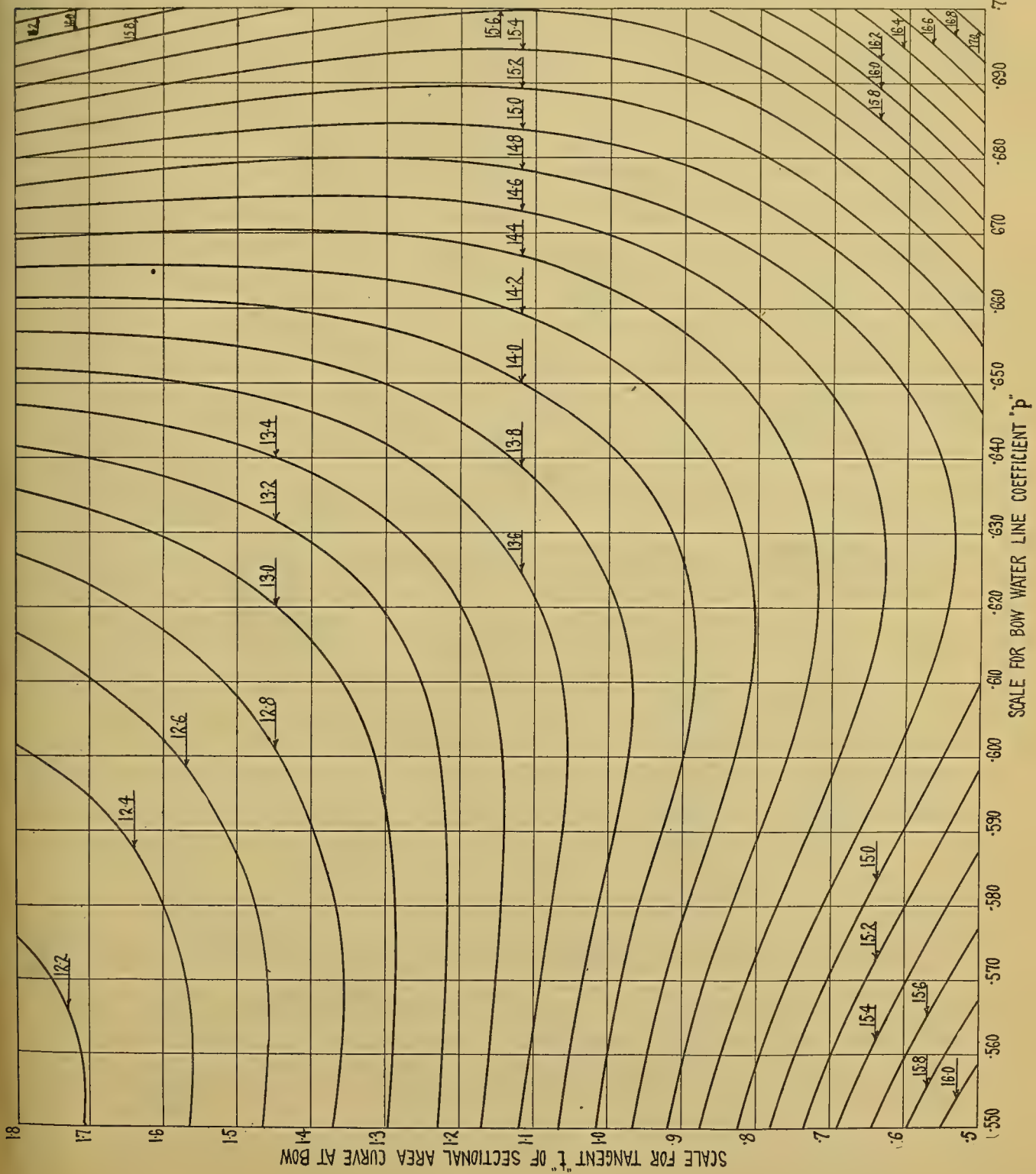
To illustrate paper on "Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance," by Naval Constructor D. W. Taylor, U. S. N., Vice-President.

FIG. 47.

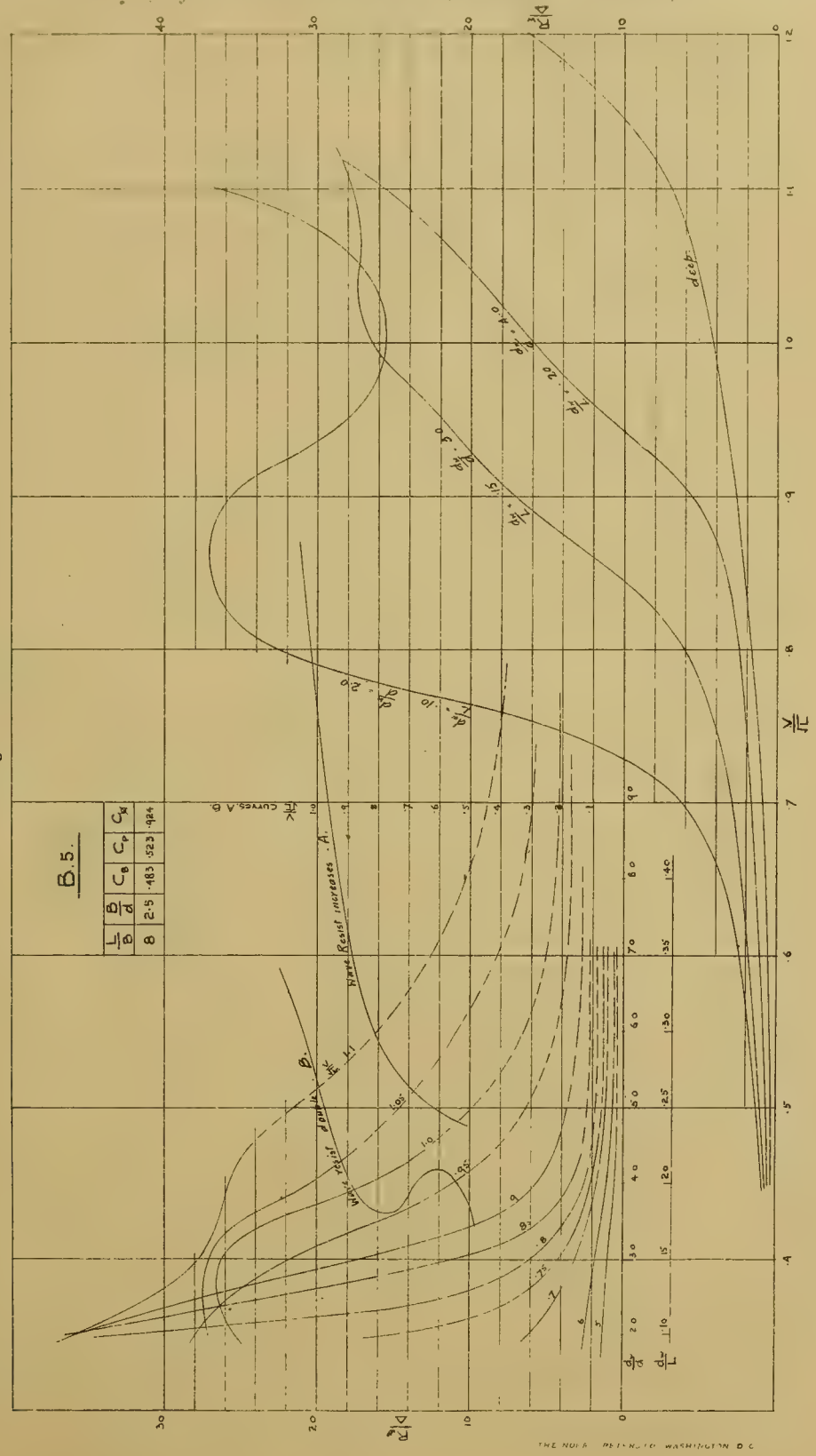
CONTOURS OF RESIDUARY RESISTANCE IN POUNDS PER TON OF DISPLACEMENT

LONGITUDINAL COEFFICIENT ·64

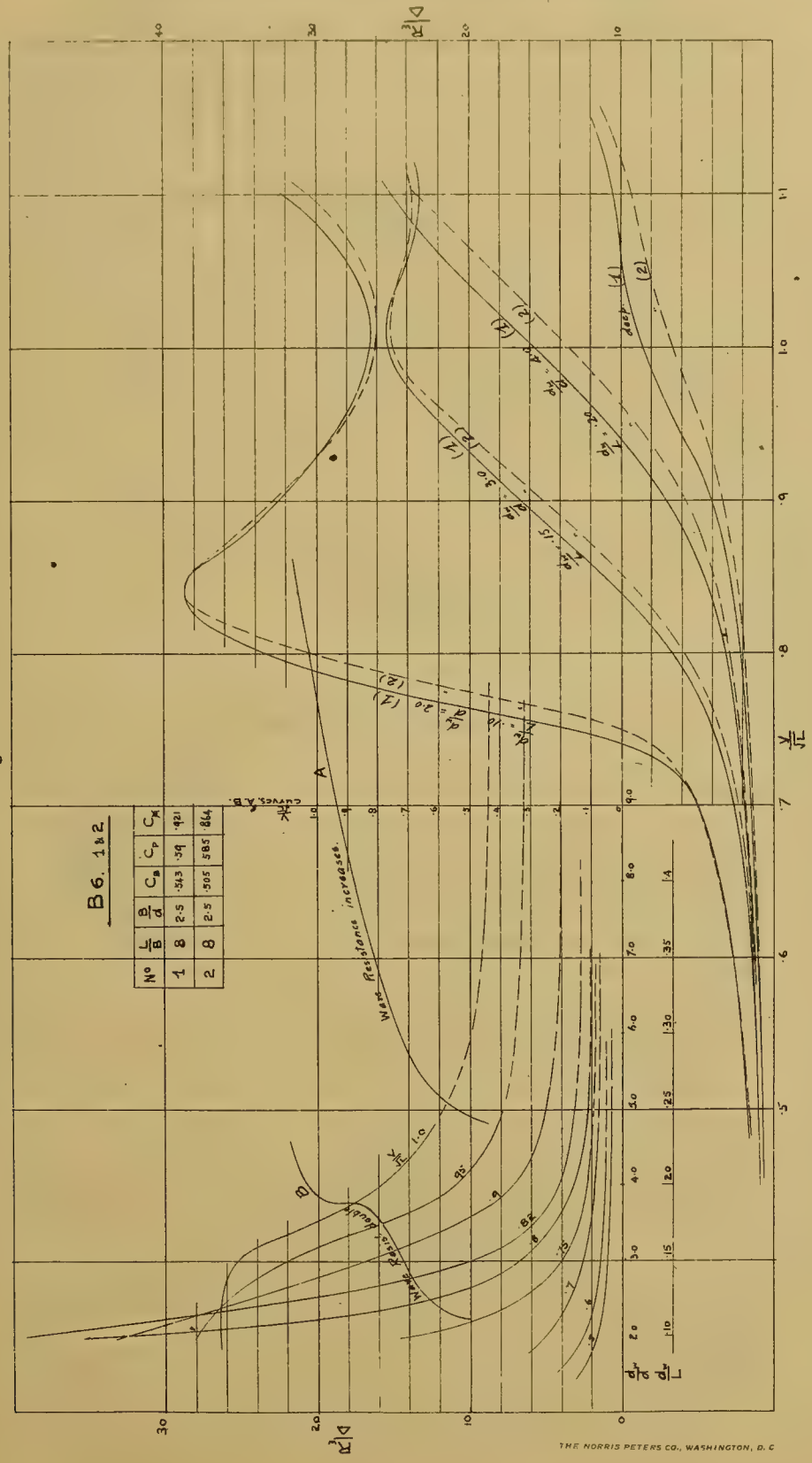
SPEED LENGTH COEFFICIENT $\frac{V}{\sqrt{L}} = 1{\cdot}10$



To illustrate paper on "The Resistance of Some Merchant Ship Types in Shallow Water," by Professor Herbert C. Sadler, Member of Council.



To illustrate paper on "The Resistance of Some Merchant Ship Types in Shallow Water," by Professor Herbert C. Sadler, Member of Council.



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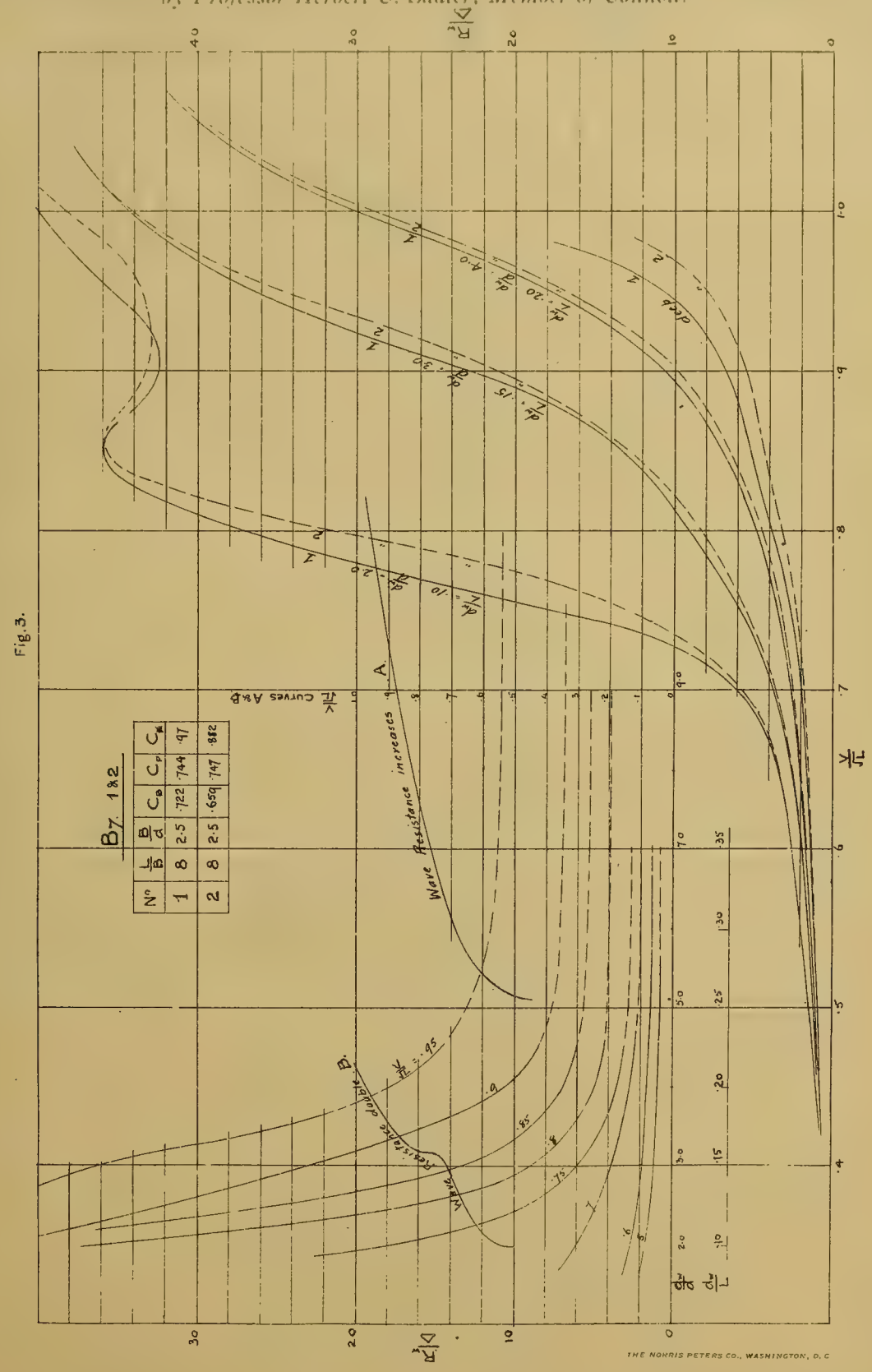
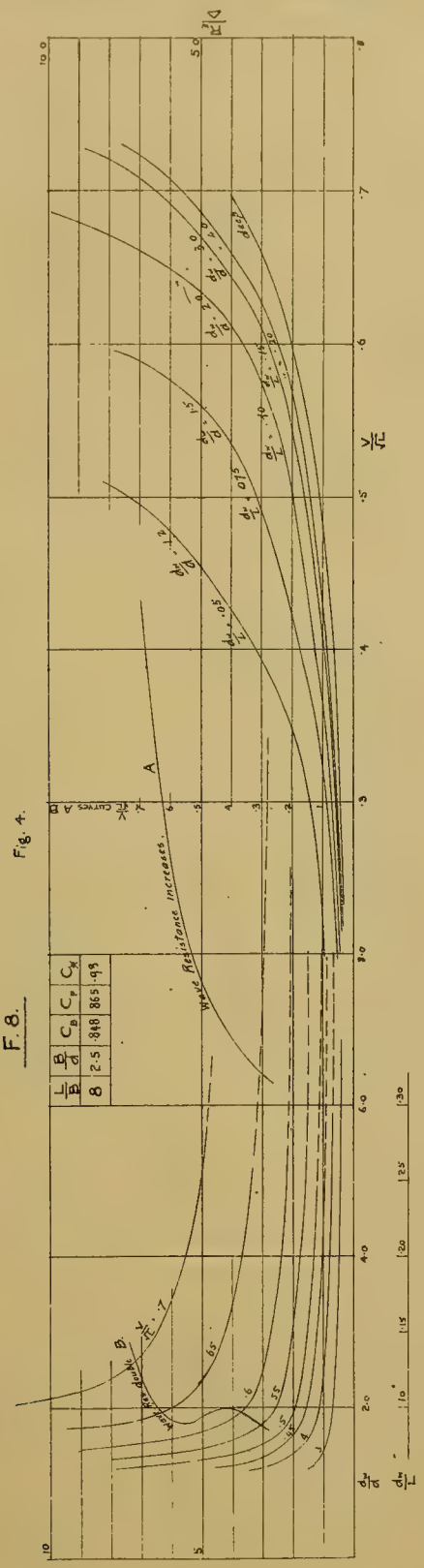


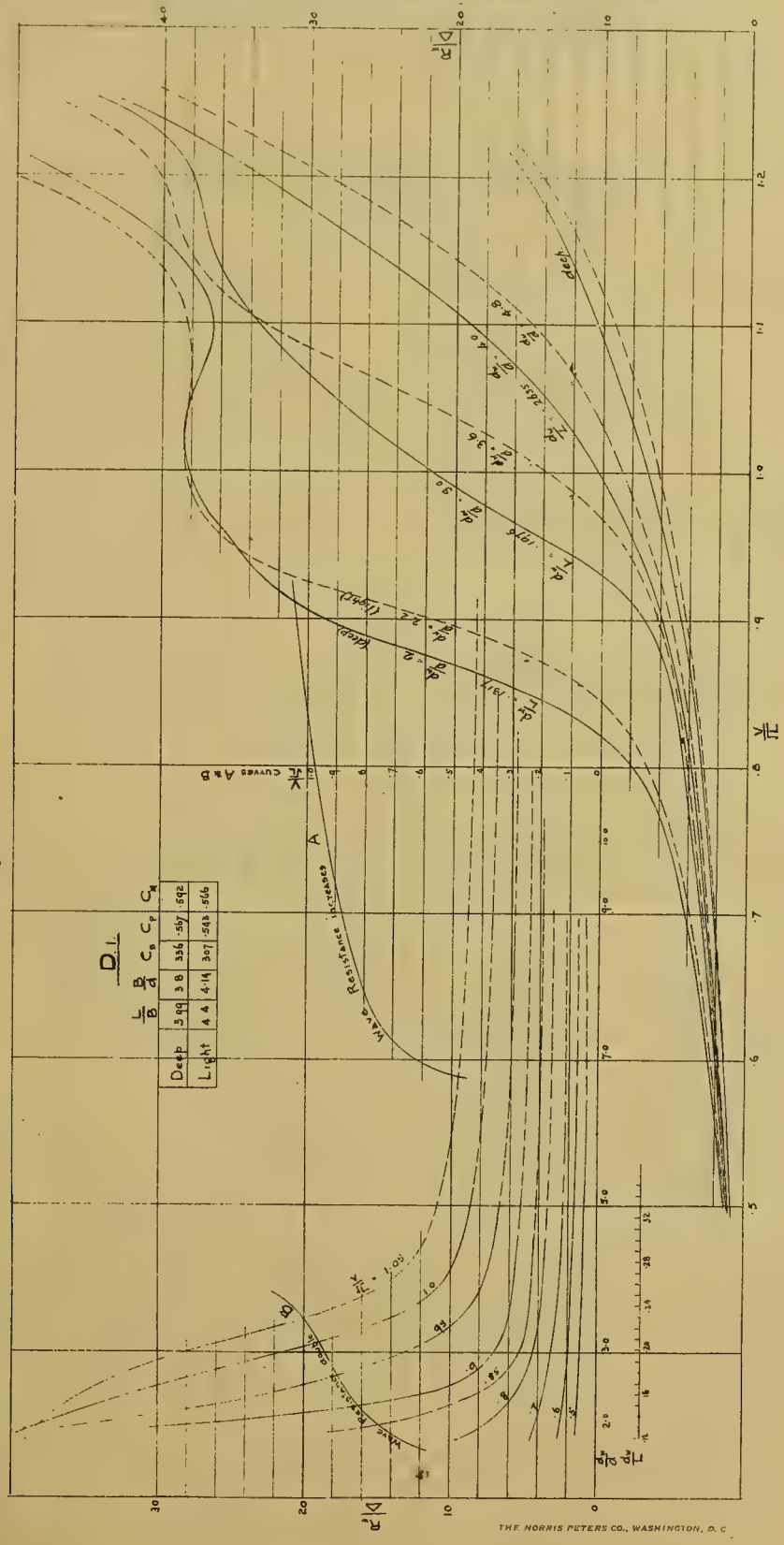
No	L/B	B/d	C_b	C_p	C_x
1	8	2.5	·722	·744	·97
2	8	2.5	·659	·747	·882

To illustrate paper on "The Resistance of Some Merchant Ship Types in Shallow Water," by Professor Herbert C. Sadler, Member of Council.

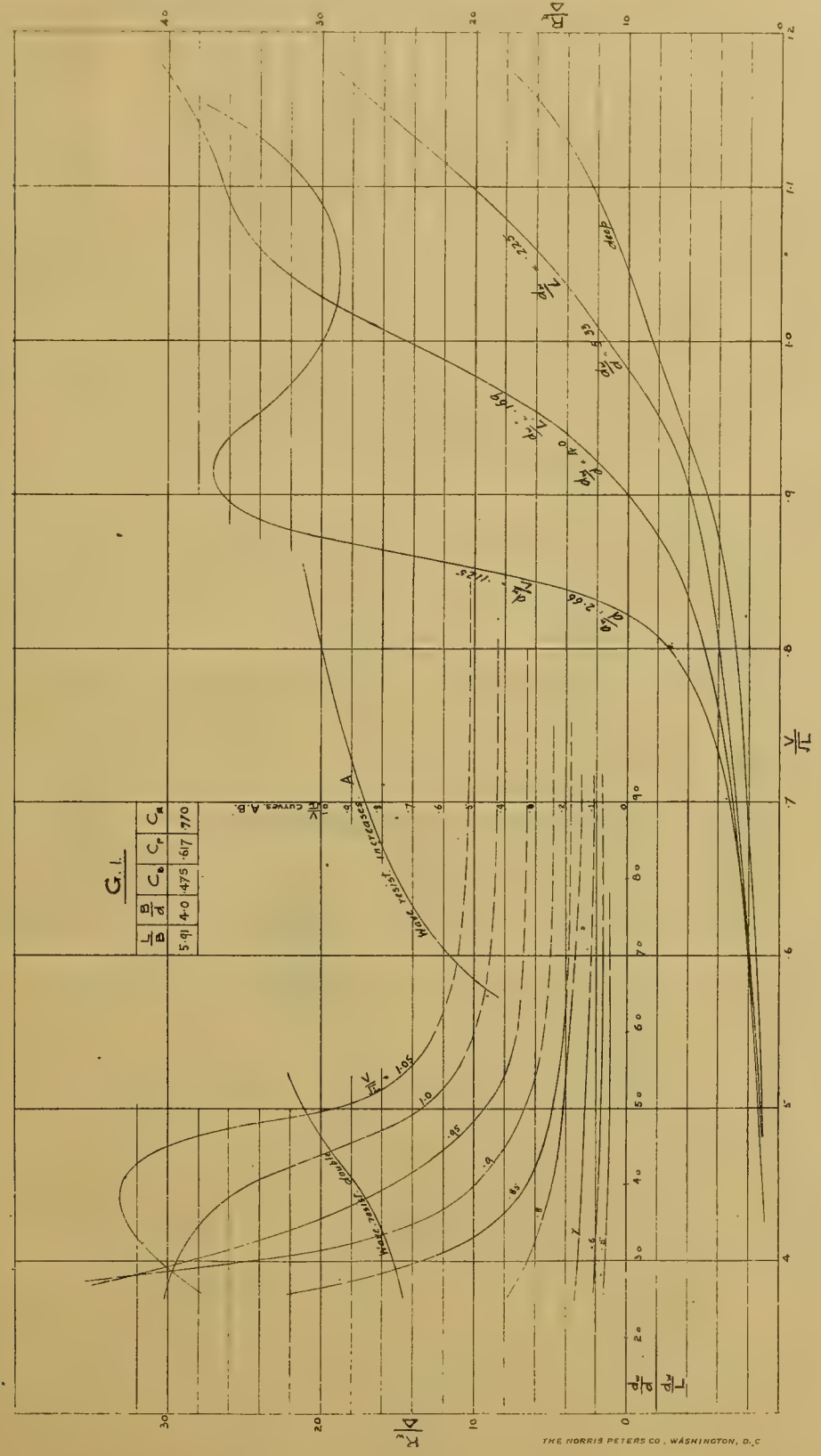


THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "The Resistance of Some Merchant Ship Types in Shallow Water," by Professor Herbert C. Sadler, Member of Council.

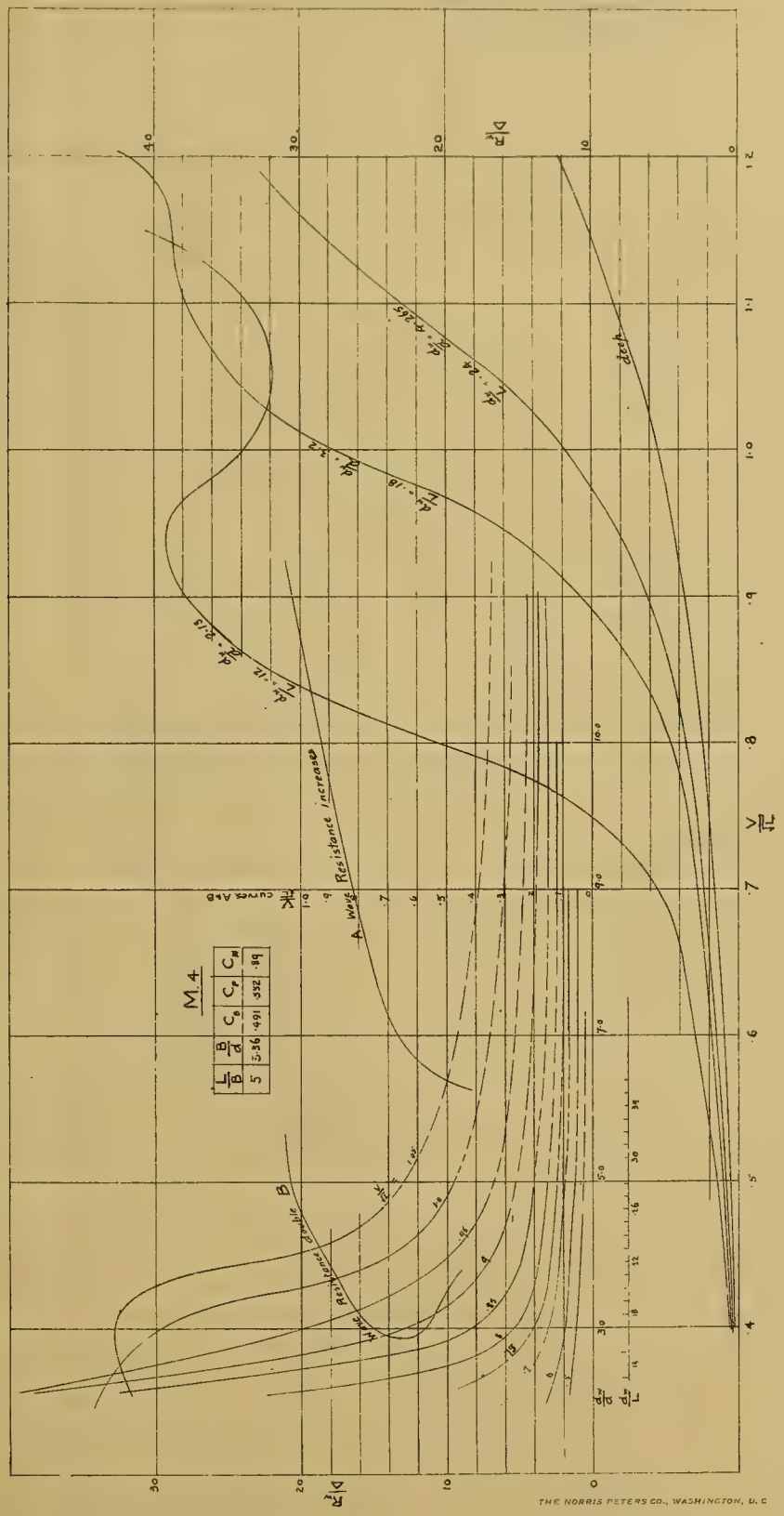


To illustrate paper on "The Resistance of Some Merchant Ship Types in Shallow Water," by Professor Herbert C. Sadler, Member of Council.



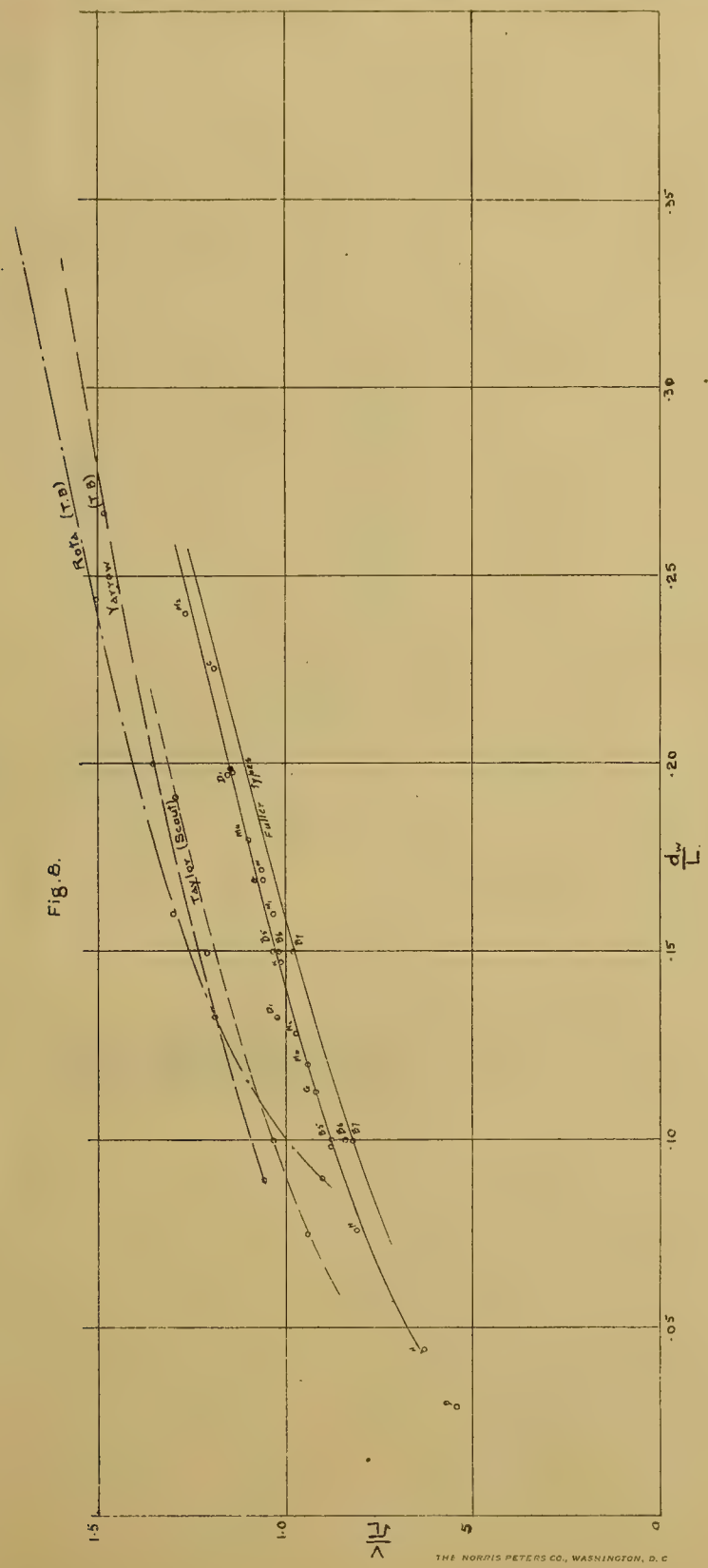
THE NORRIS PETERS CO., WASHINGTON, D.C.

To illustrate paper on "The Resistance of Some Merchant Ship Types in Shallow Water," by Professor Herbert C. Sadler, Member of Council.



THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "The Resistance of Some Merchant Ship Types in Shallow Water," by Professor Herbert C. Sadler, Member of Council.



THE NORRIS PETERS CO., WASHINGTON, D. C

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council

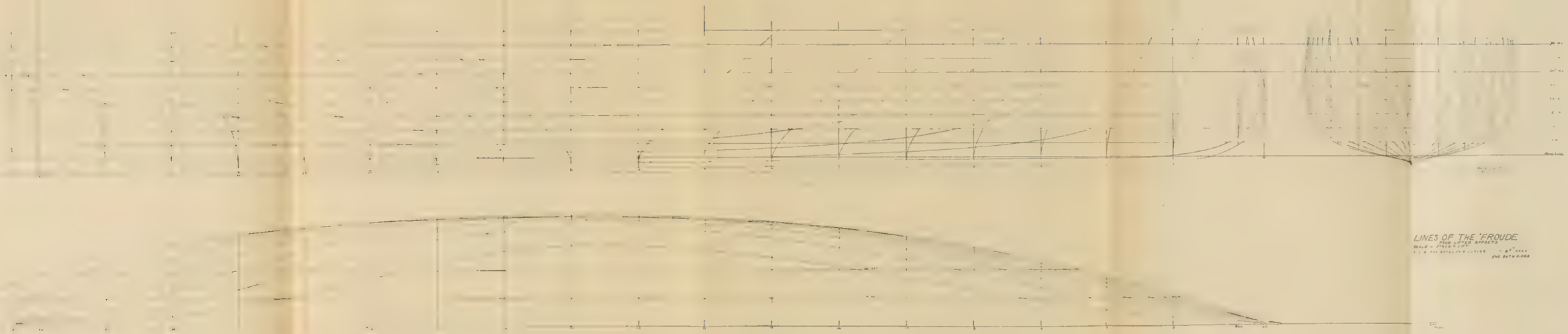


Fig. 1

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council

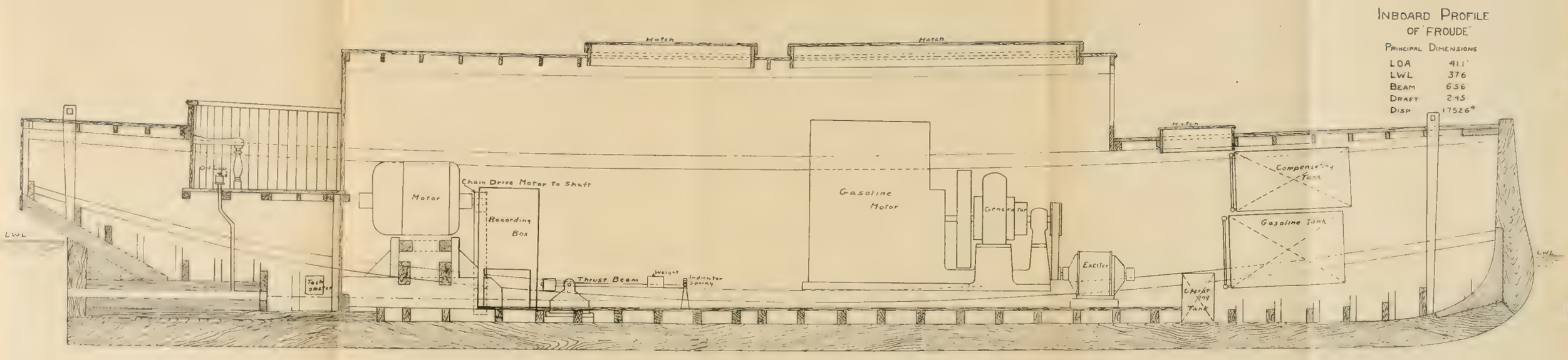


Fig. 2

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

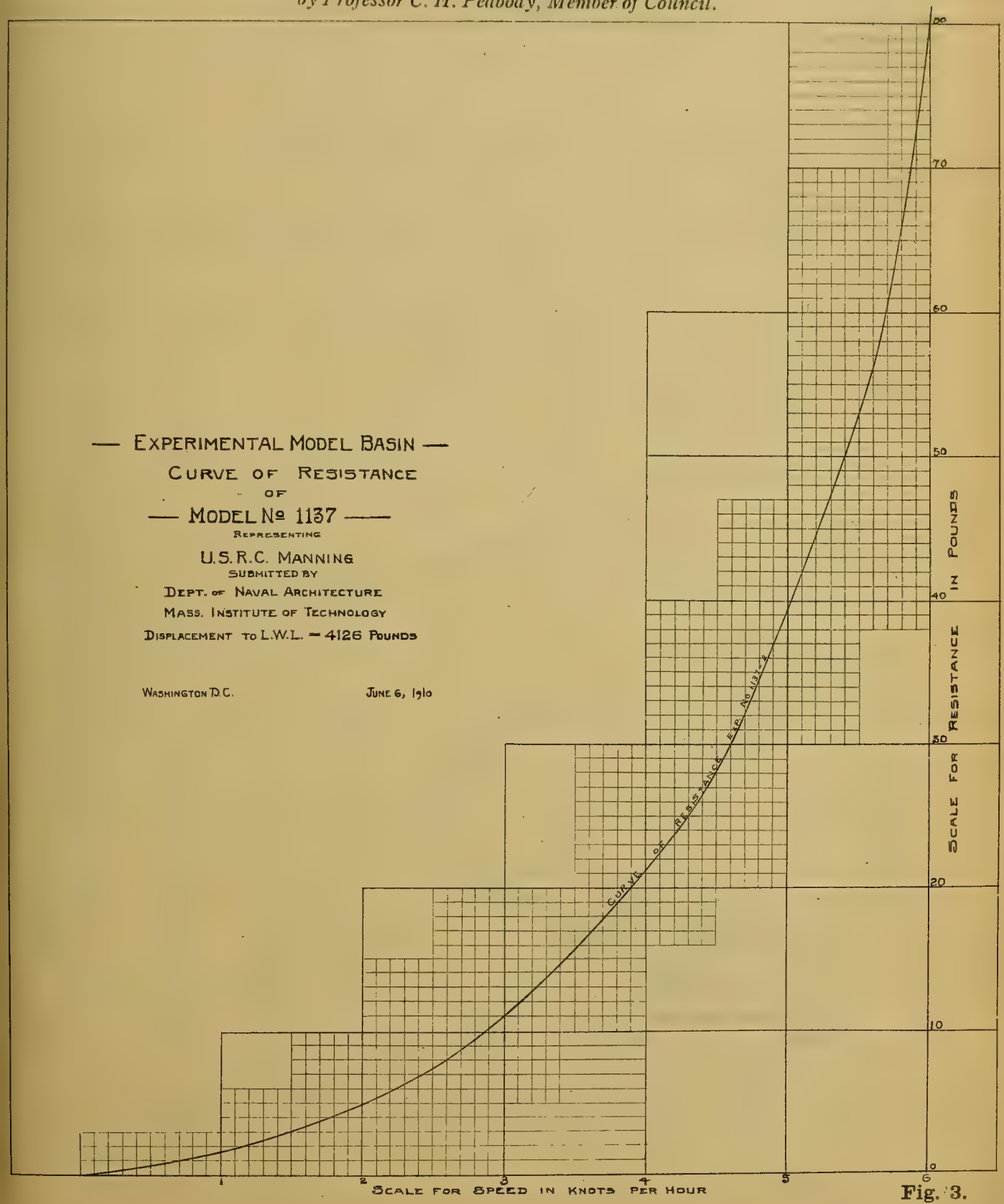


Fig. 3.

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To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

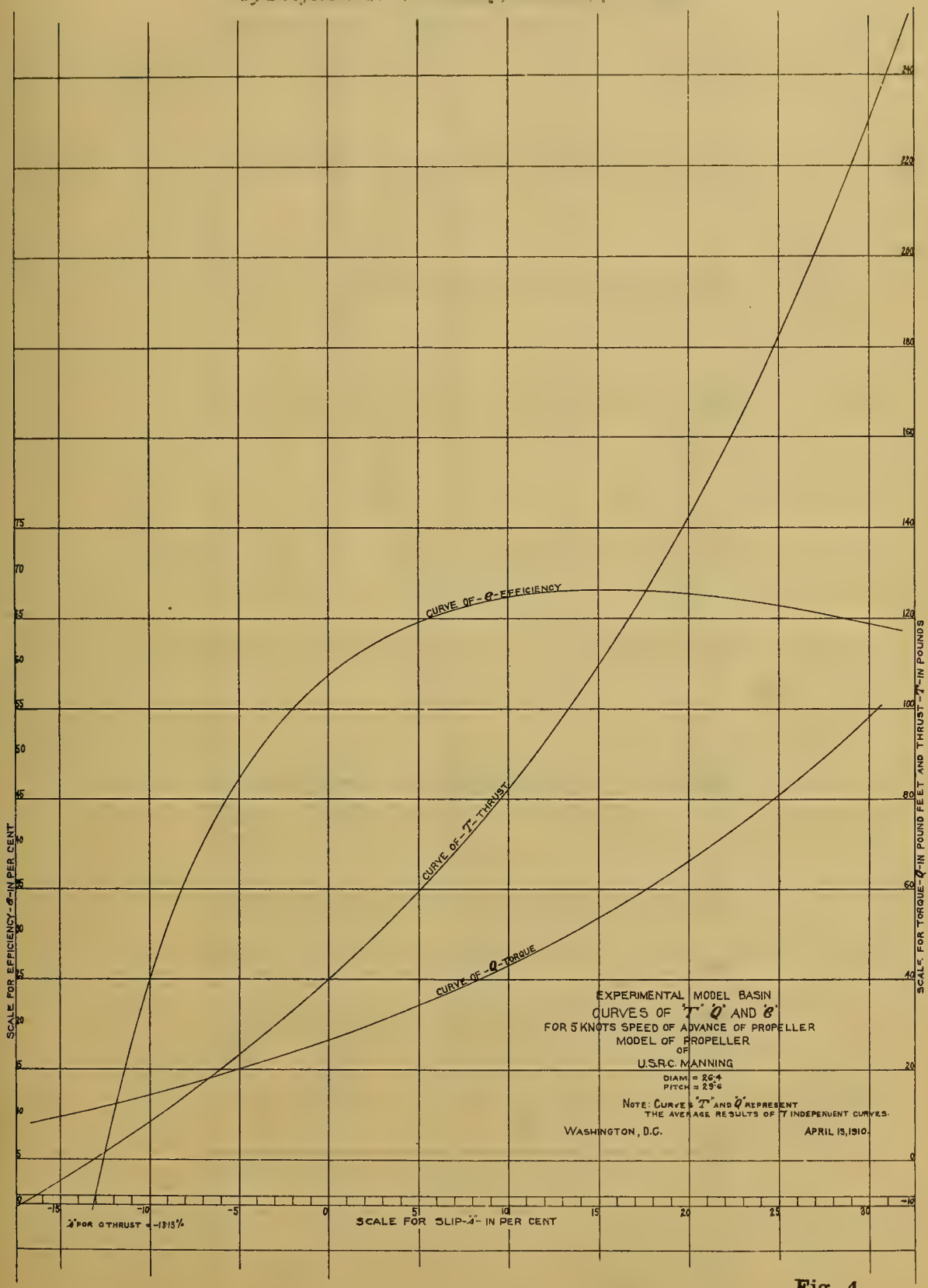

Fig. 4.

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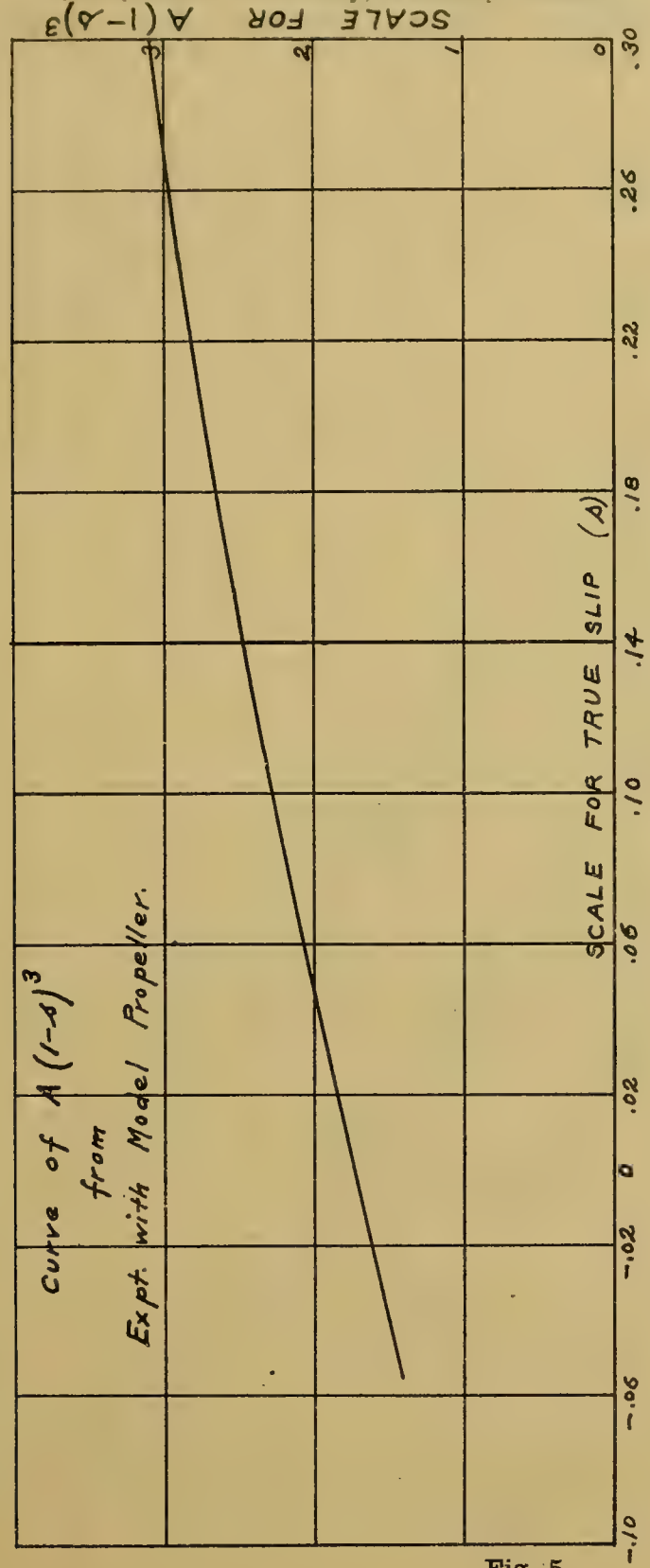

Fig. 5.

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

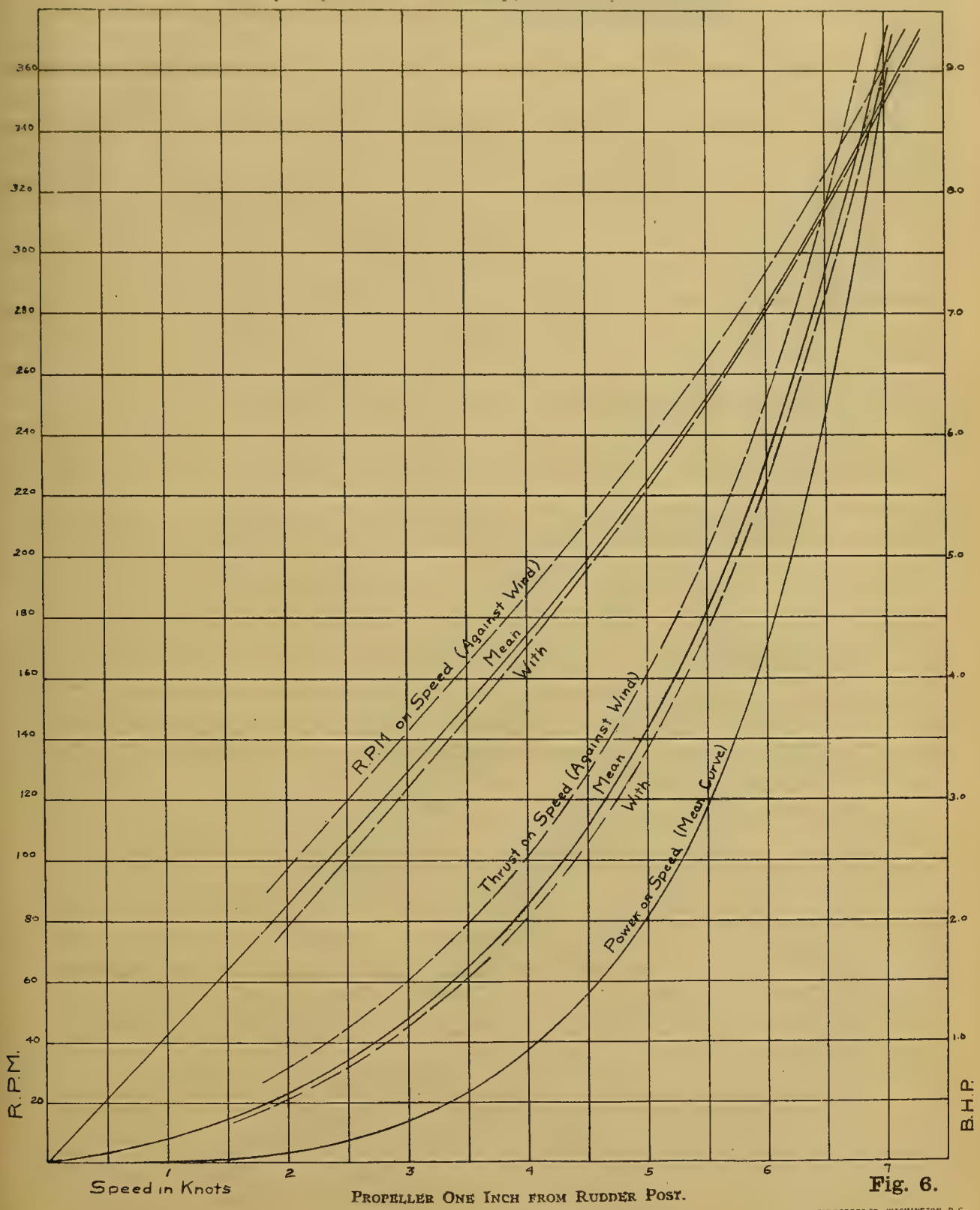

Fig. 6.

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To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

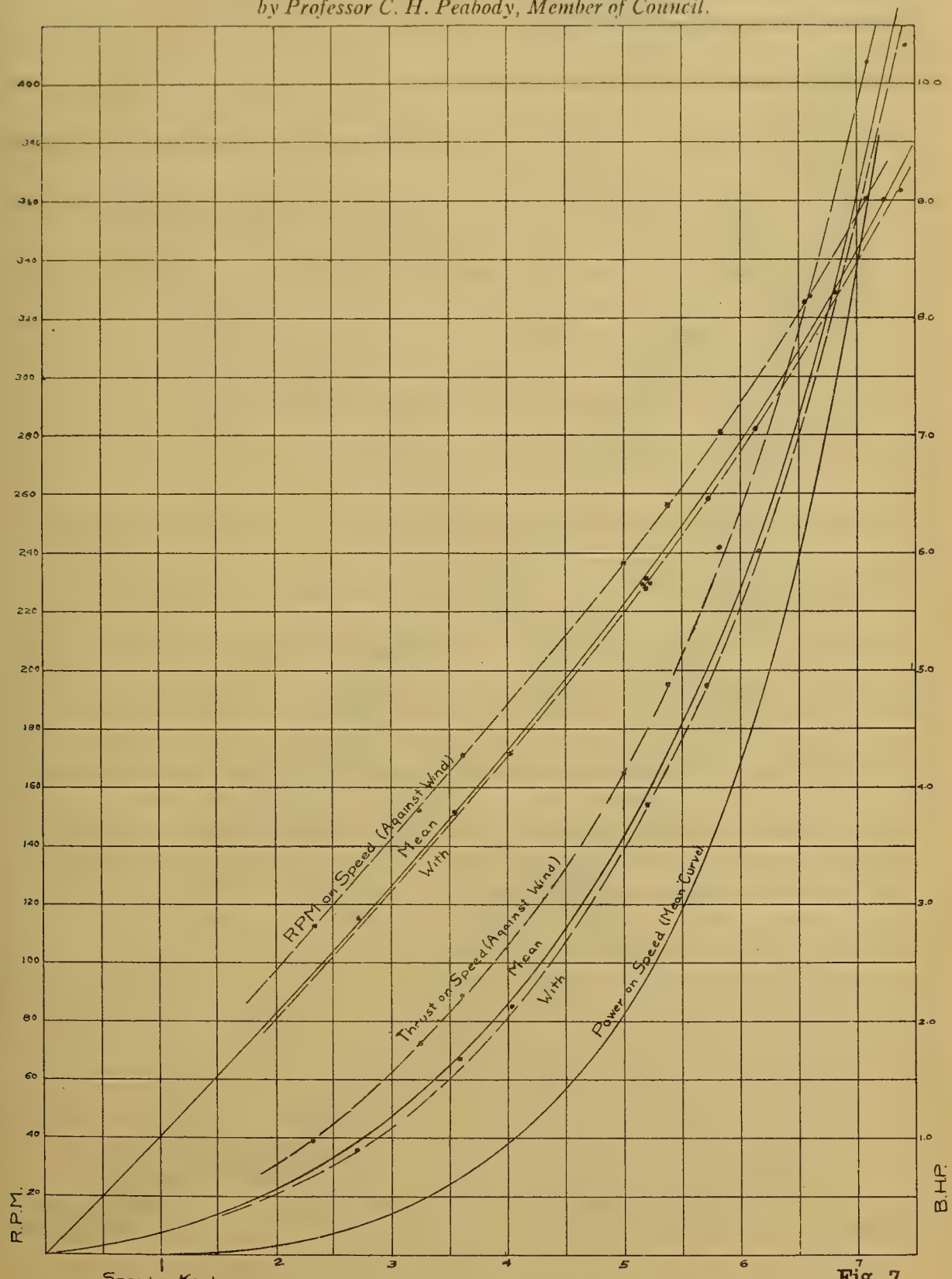

Fig. 7.

PROPELLER THREE INCHES FROM RUDDER POST.

THE NORRIS PETERS CO., WASHINGTON, D. C.

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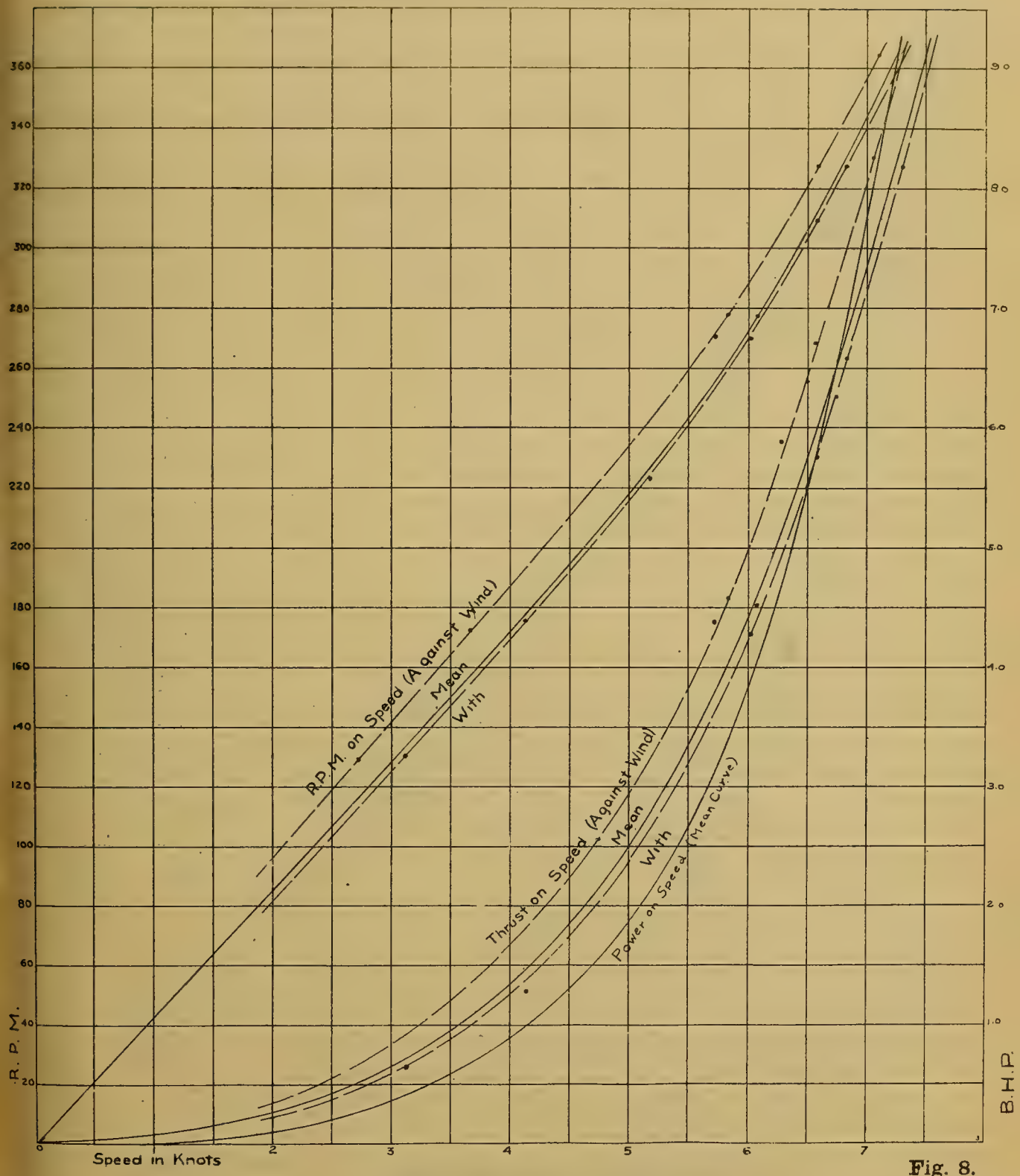

Fig. 8.

PROPELLER SIX INCHES FROM RUDDER POST.

THE HORRIS PRINTING CO., WASHINGTON, D. C.

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

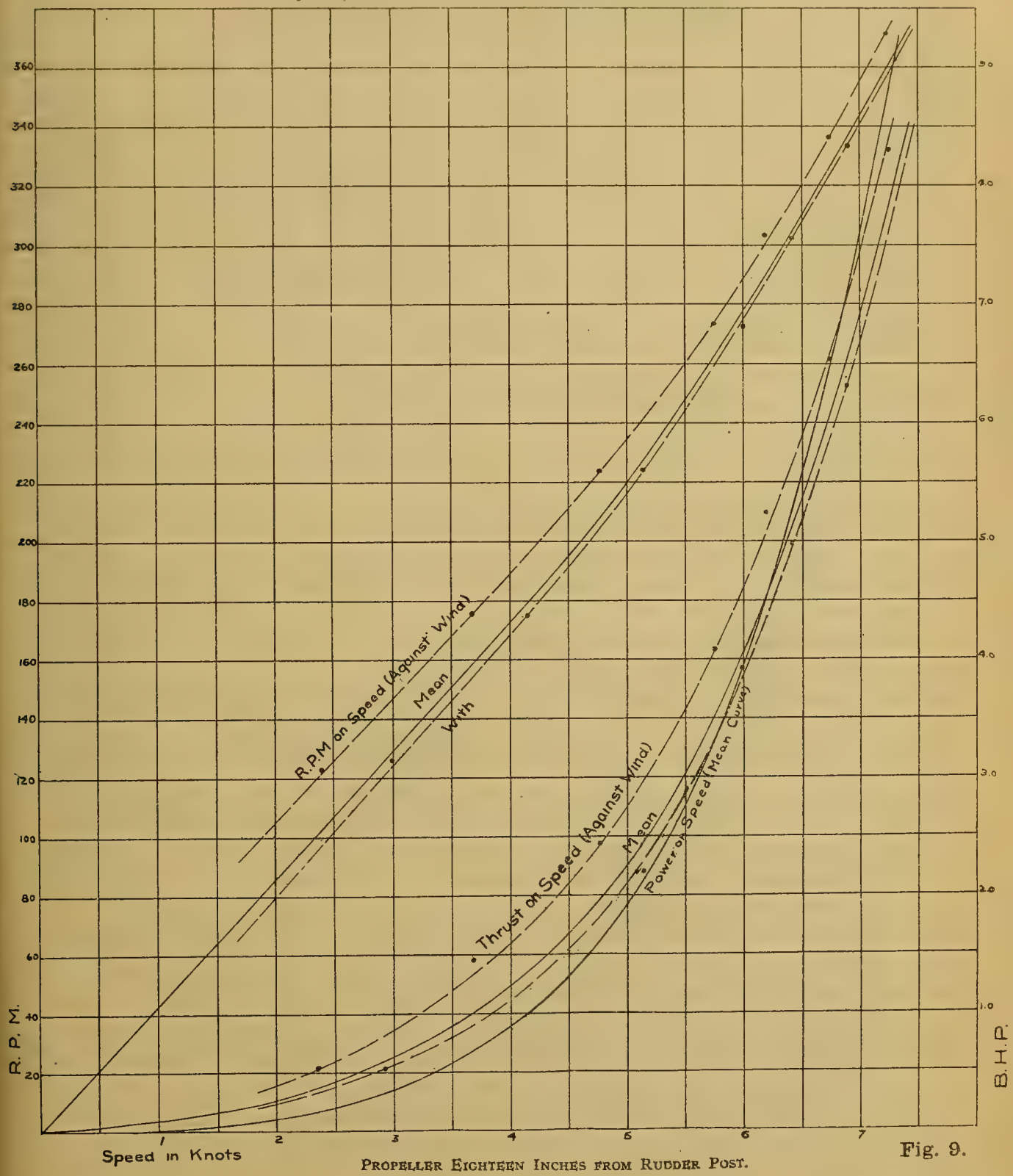

Fig. 9.

PROPELLER EIGHTEEN INCHES FROM RUDDER POST.

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

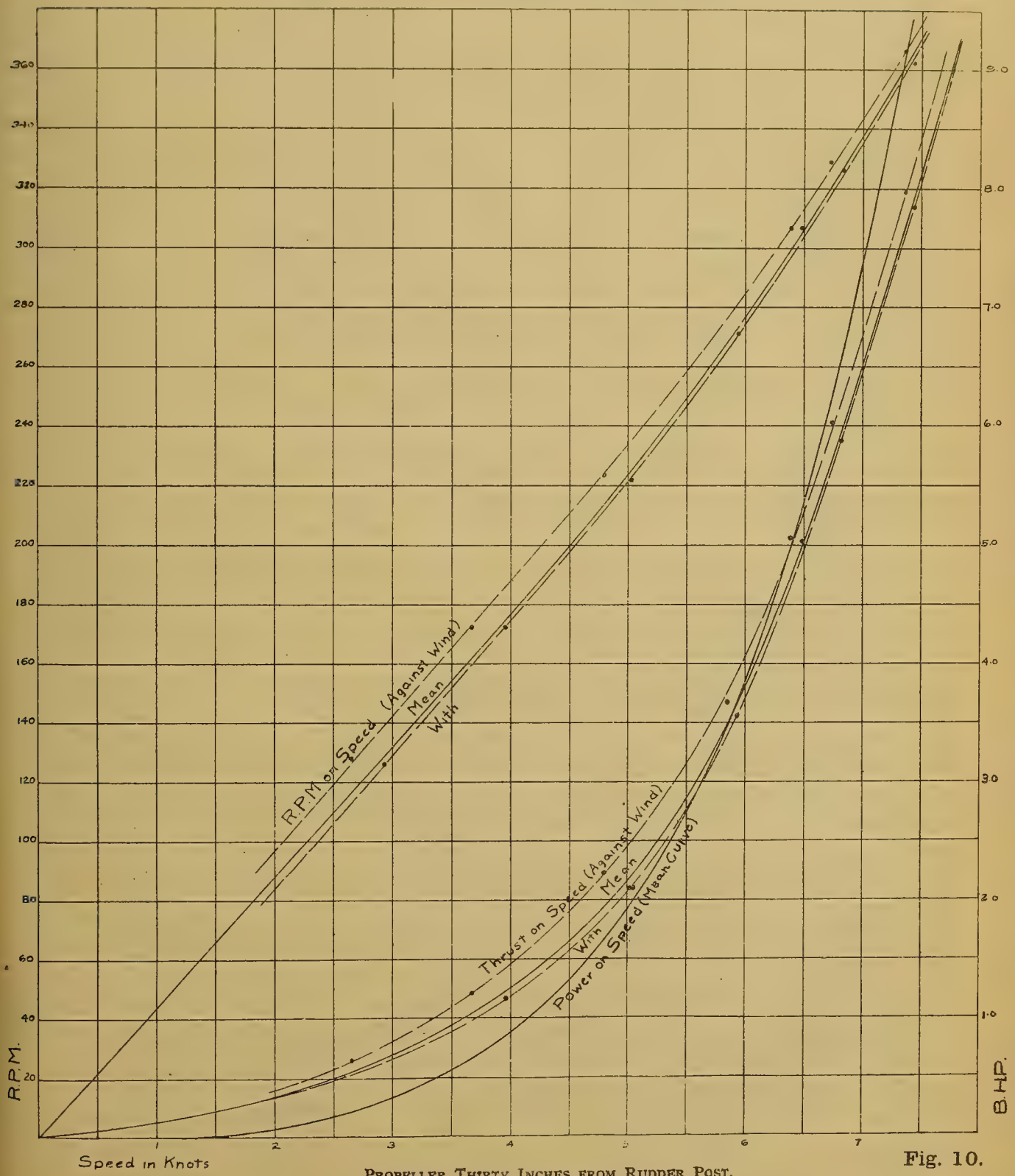

Fig. 10.

PROPELLER THIRTY INCHES FROM RUDDER POST.

THE NORRIS PETERS CO. WASHINGTON, D.C.

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

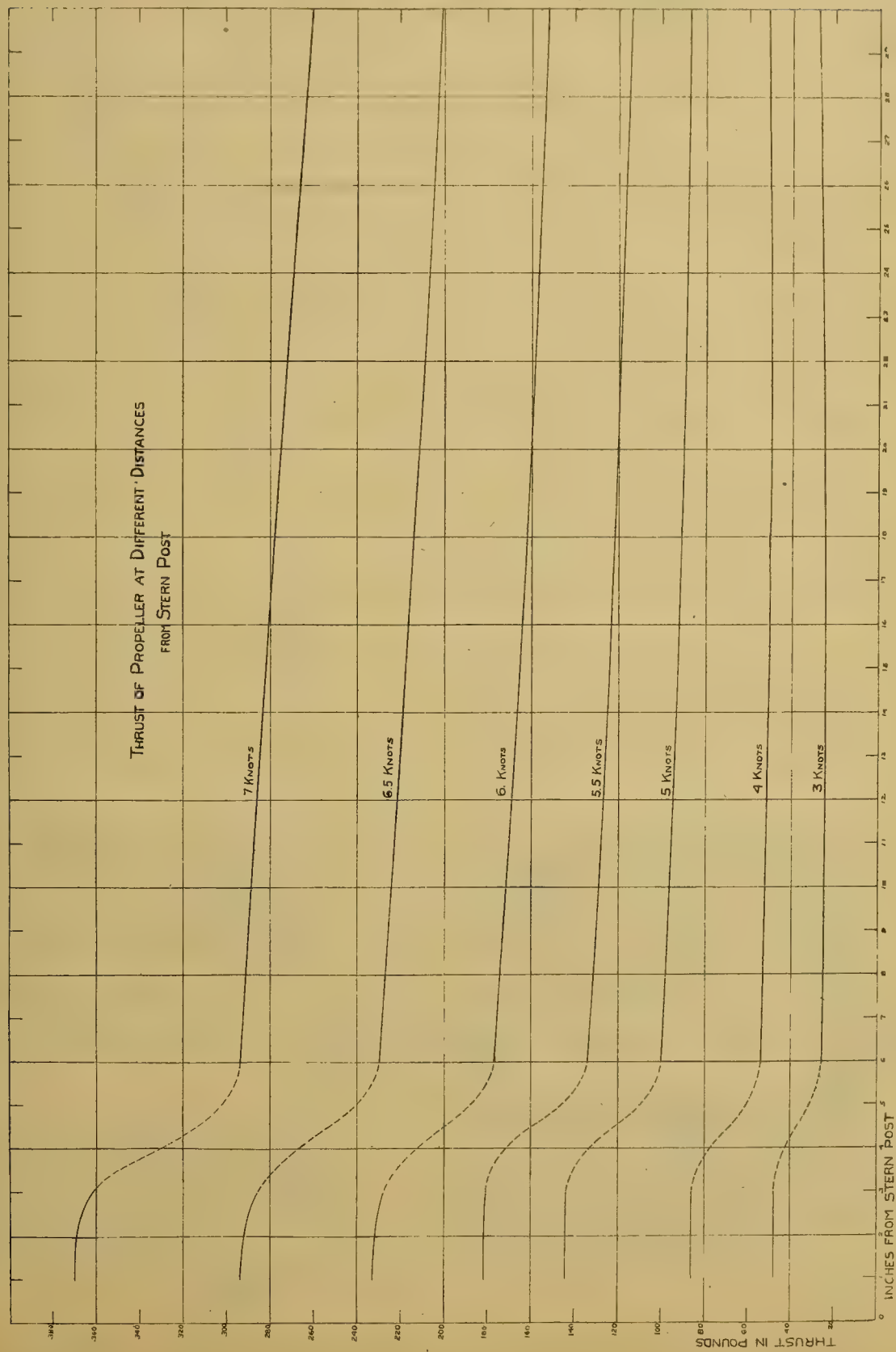

Fig. 11.

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To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

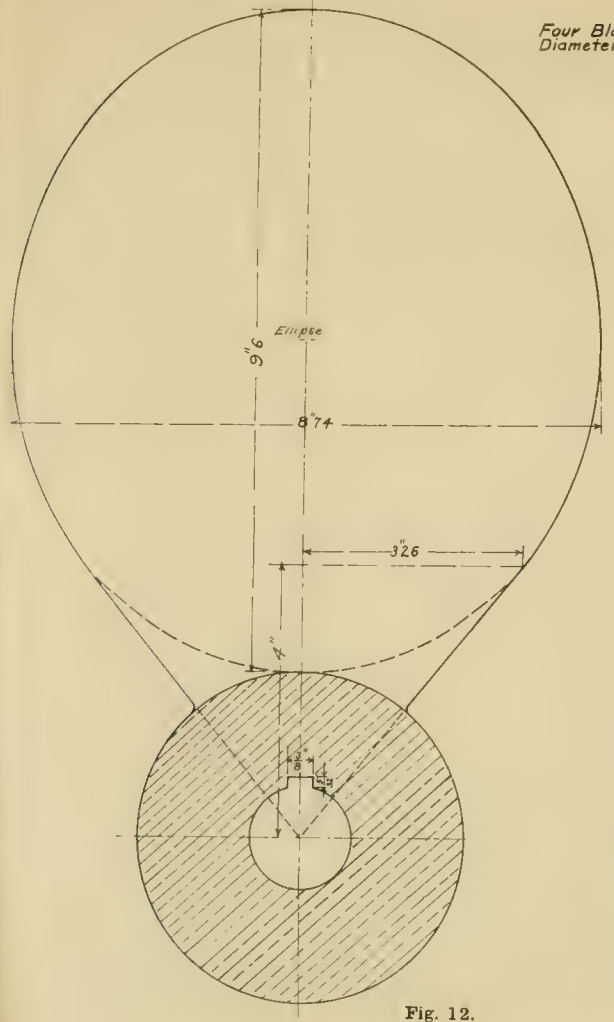

Fig. 12.

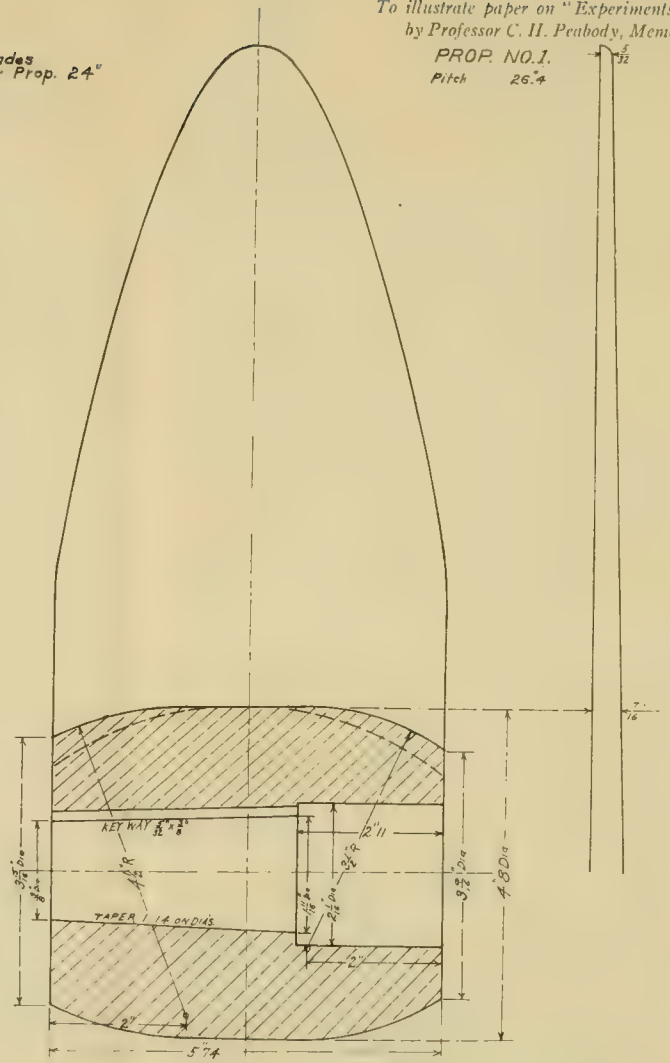

Fig. 13.

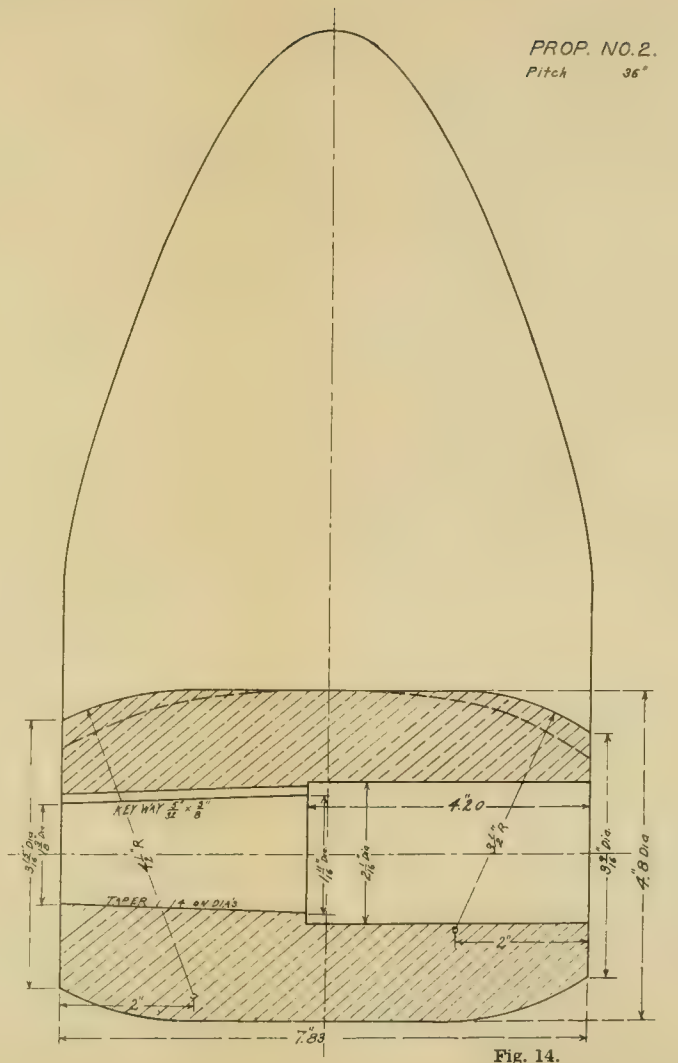

Fig. 14.

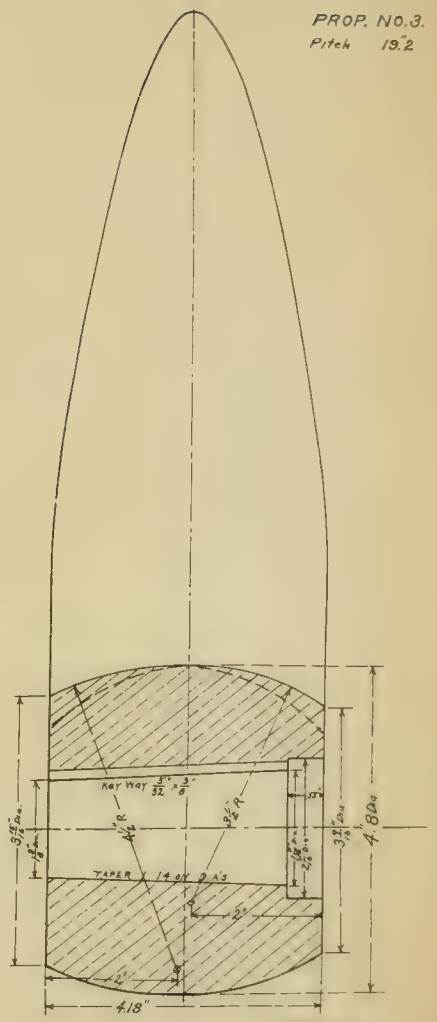

Fig. 15

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

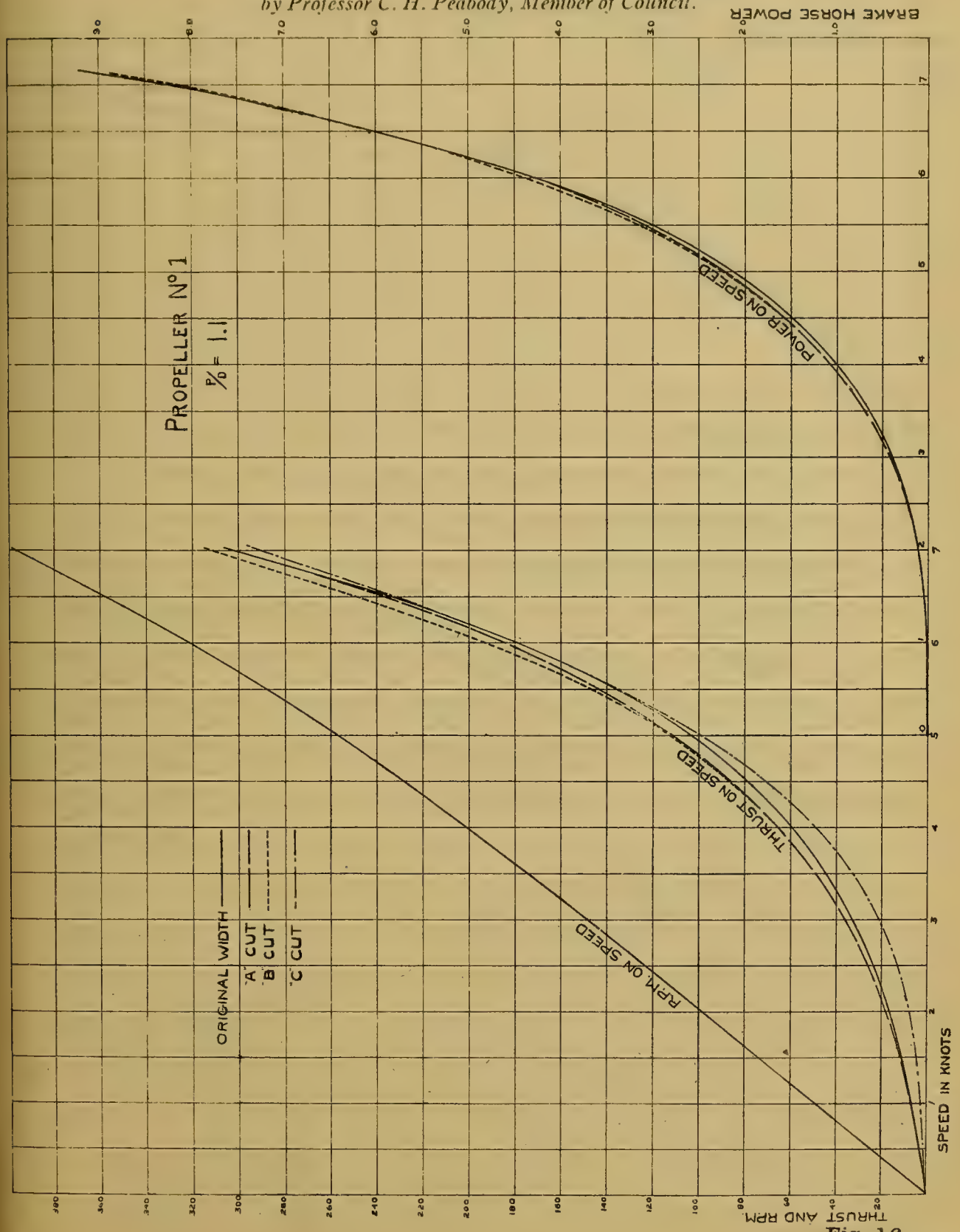

Fig. 16.

H.F. NORRIS PETERS CO., WASHINGTON, D.C.

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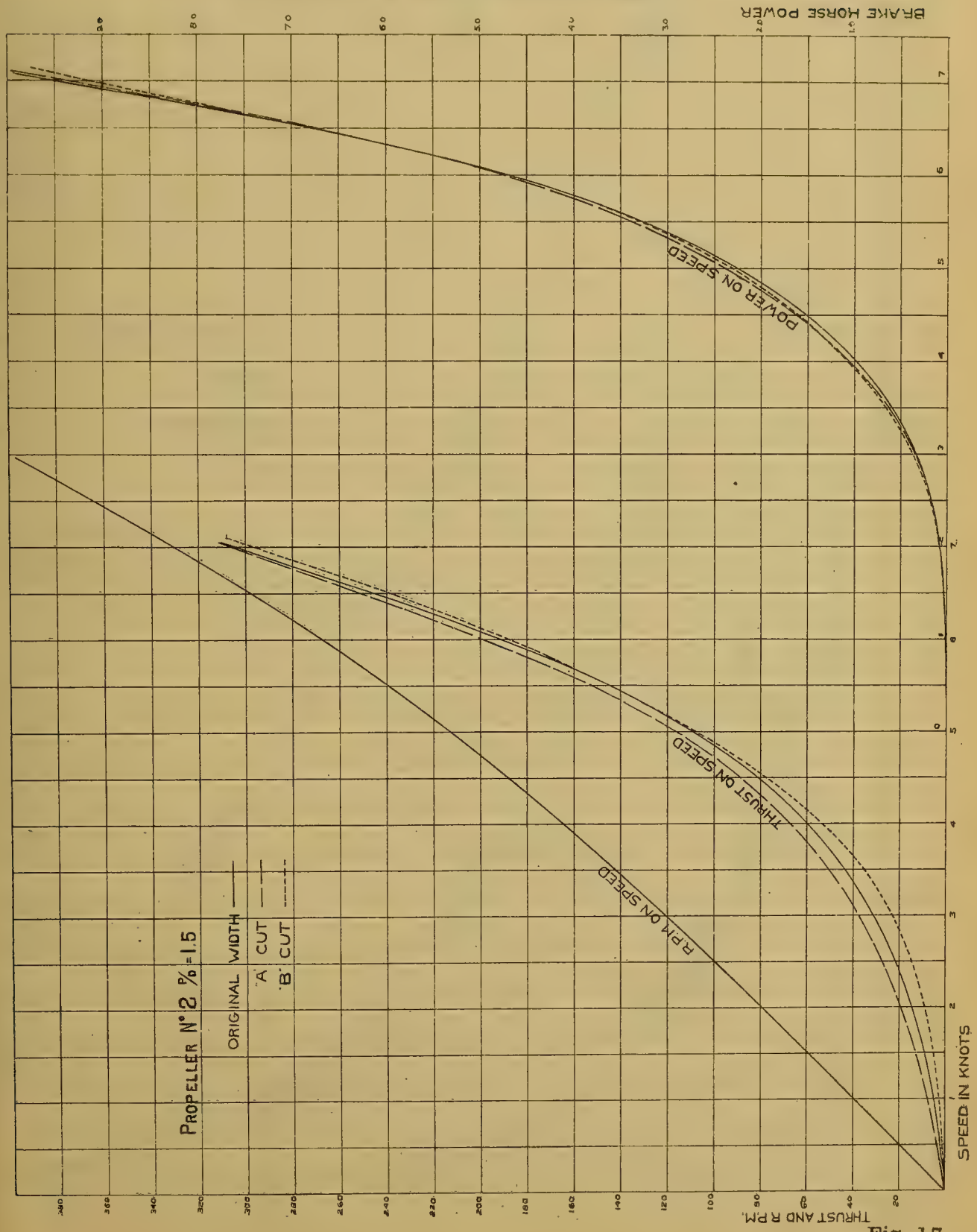

Fig. 17.

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To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

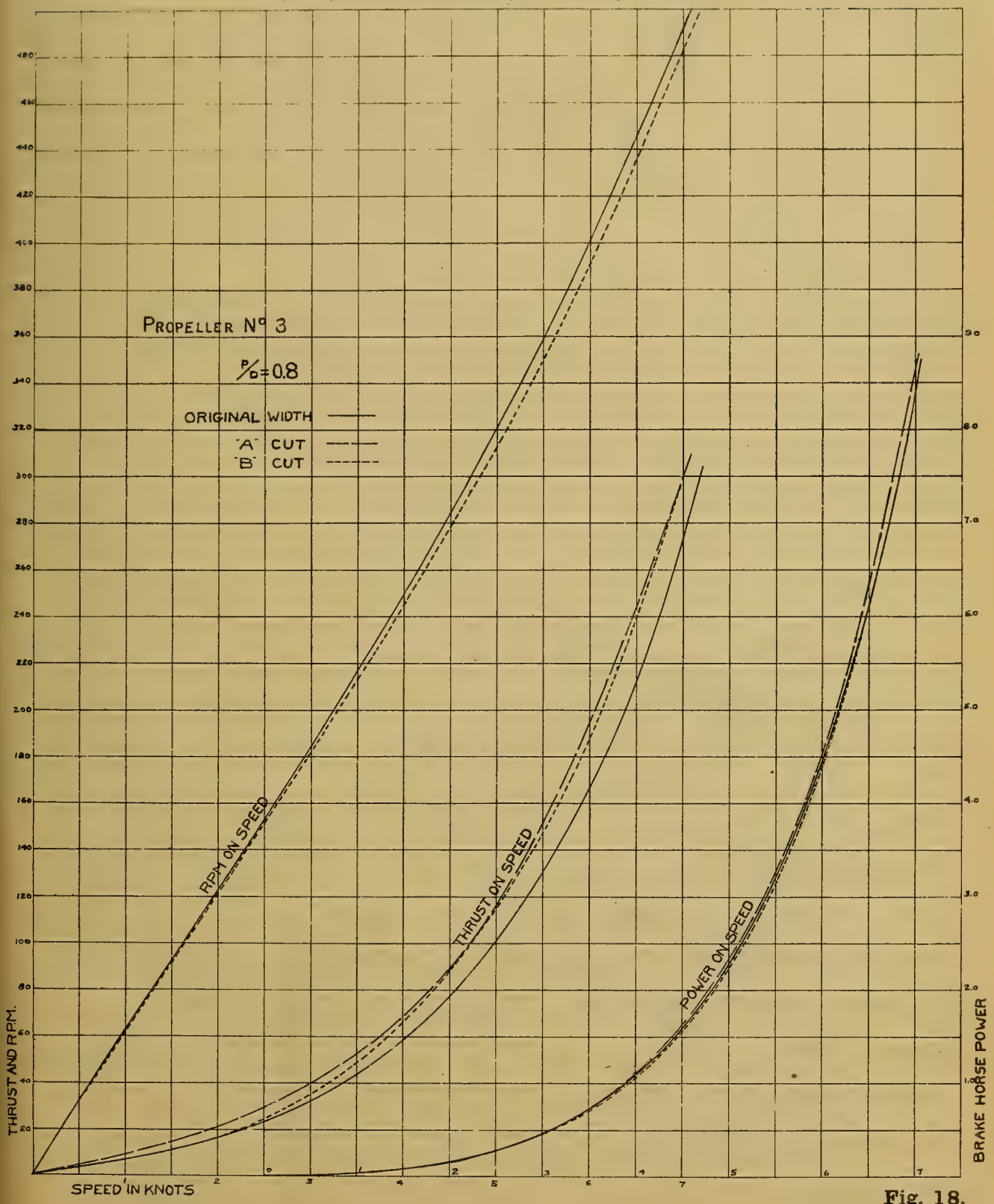

Fig. 18.

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To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

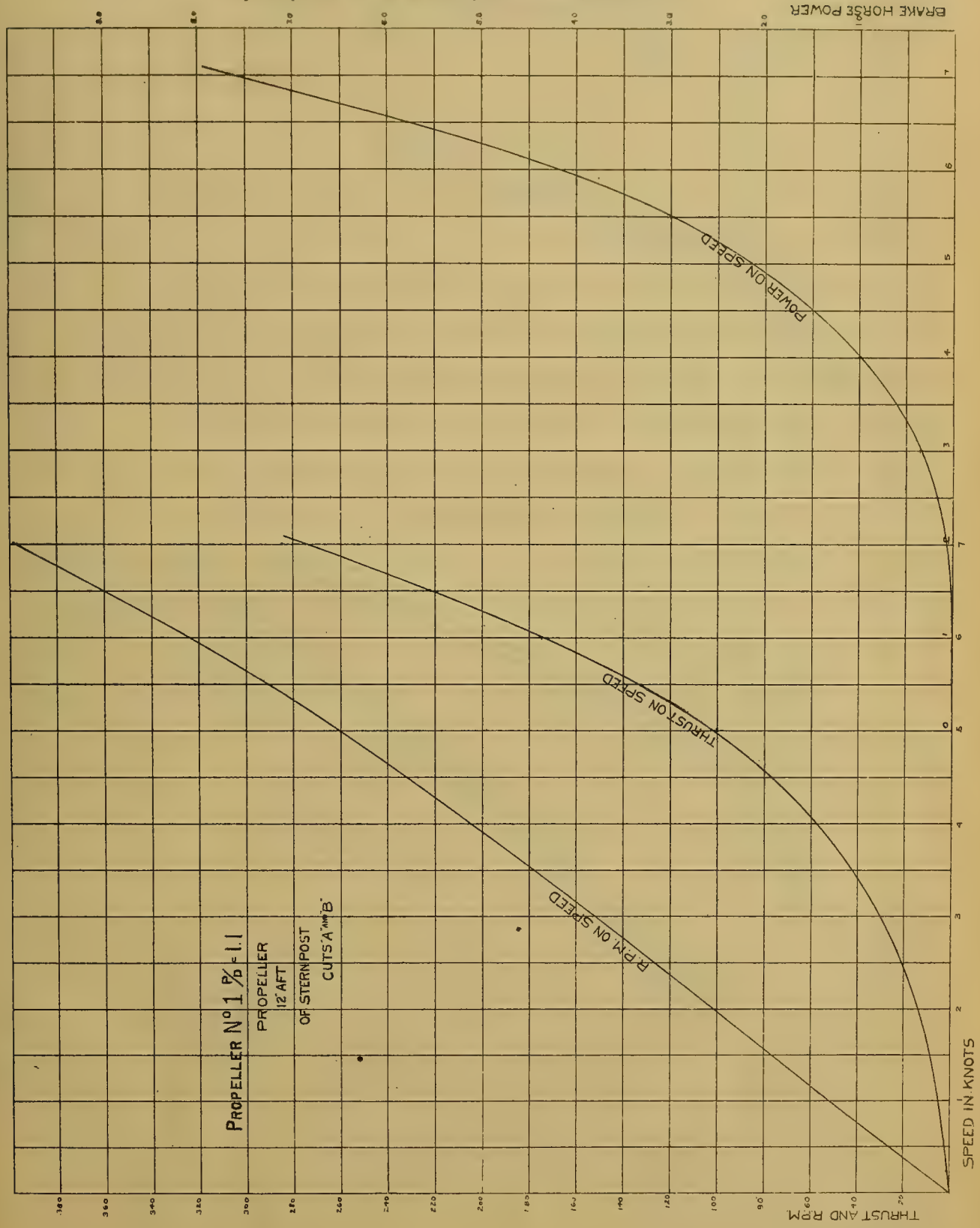

Fig. 19.

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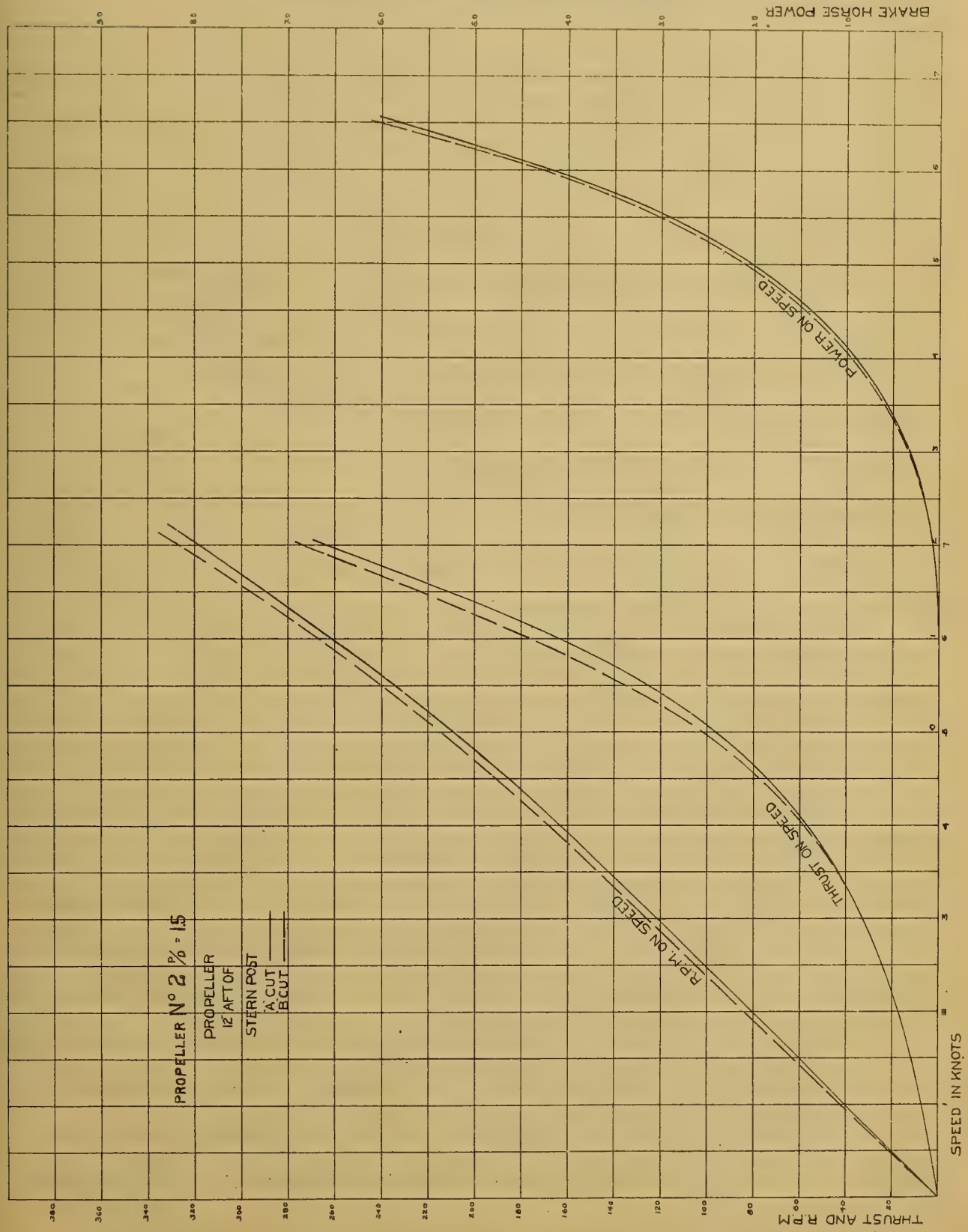

Fig. 20.

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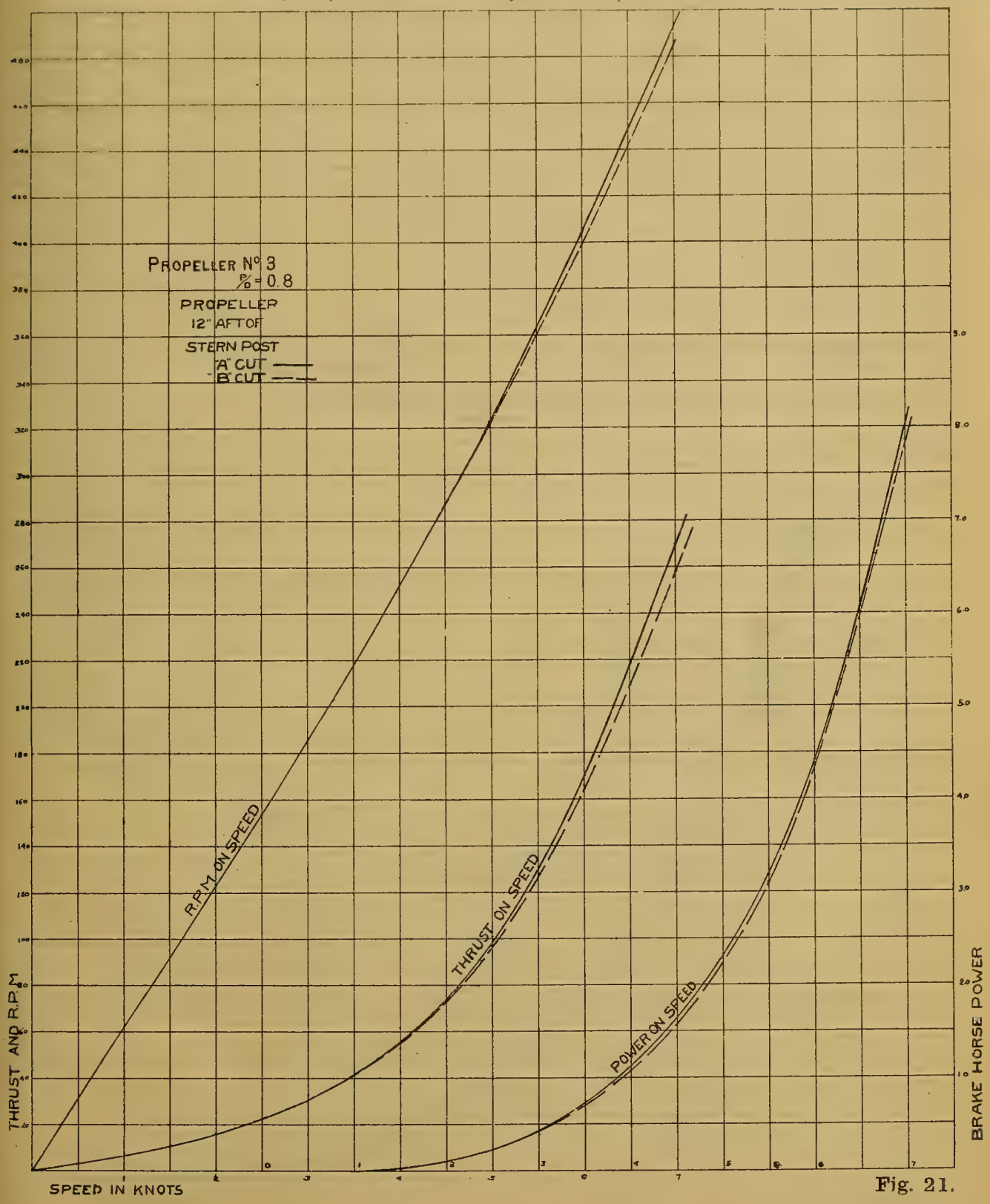

Fig. 21.

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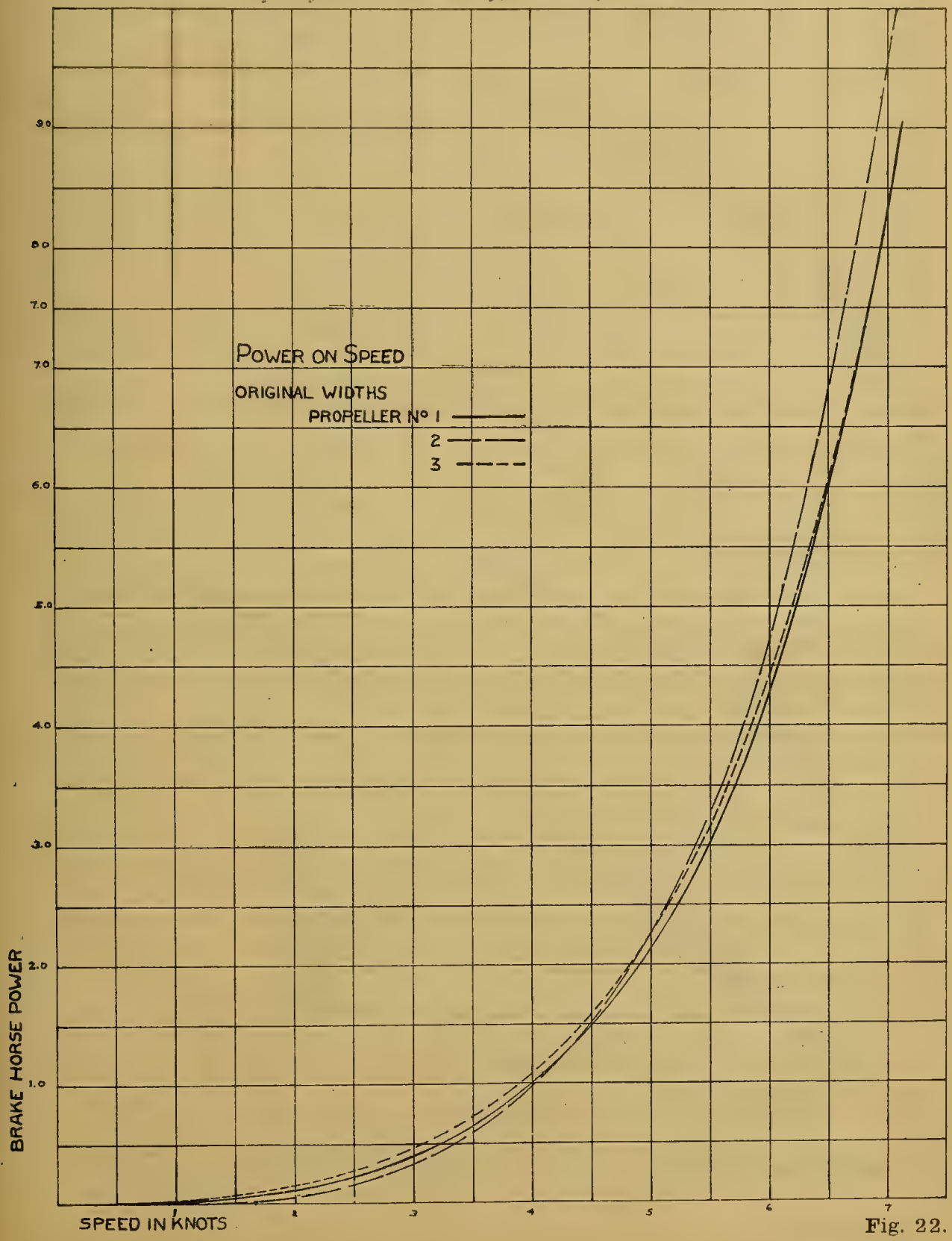

Fig. 22.

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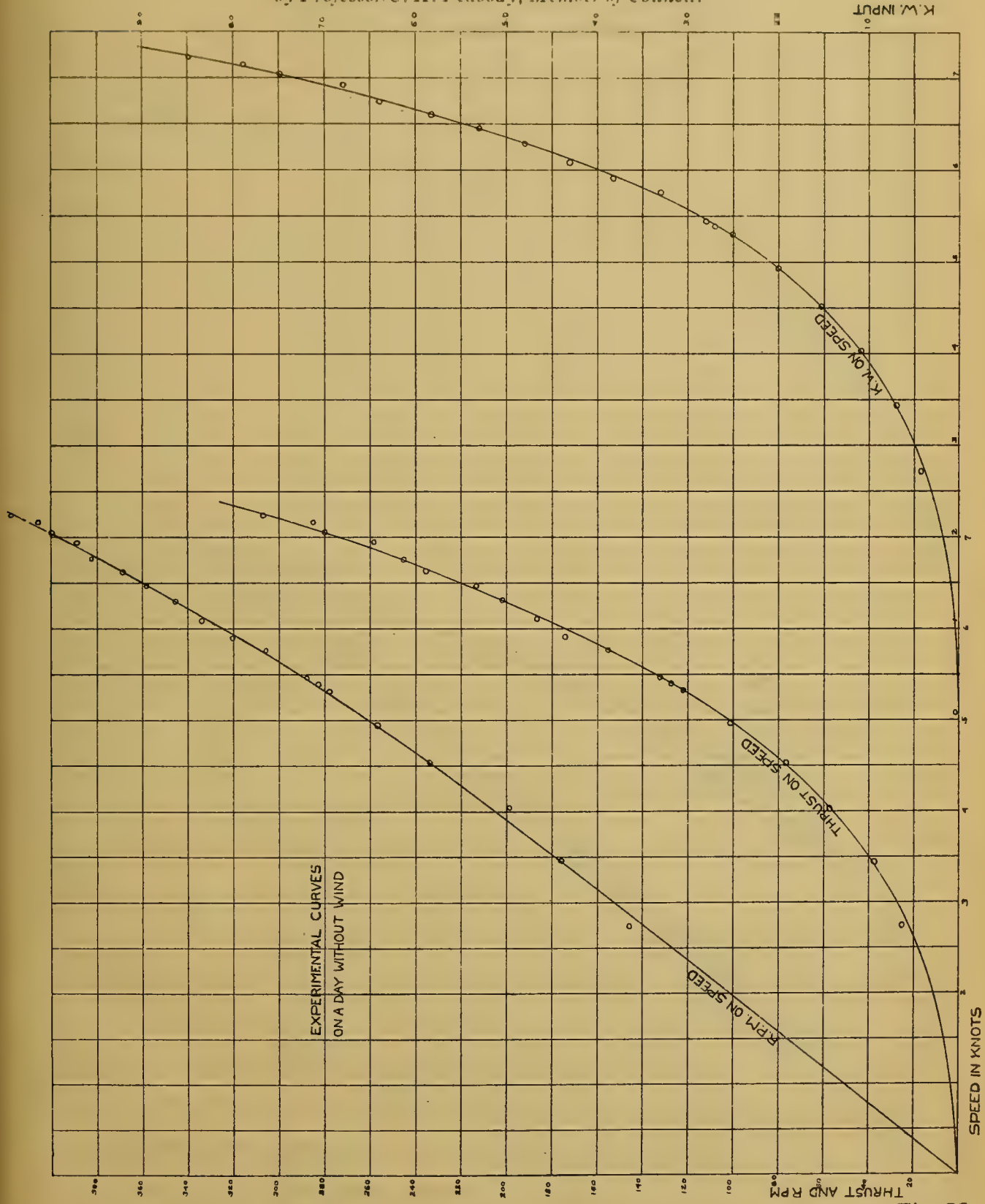

Fig. 23.

THE GOOSIS PRESS CO., WASHINGTON, D. C.

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

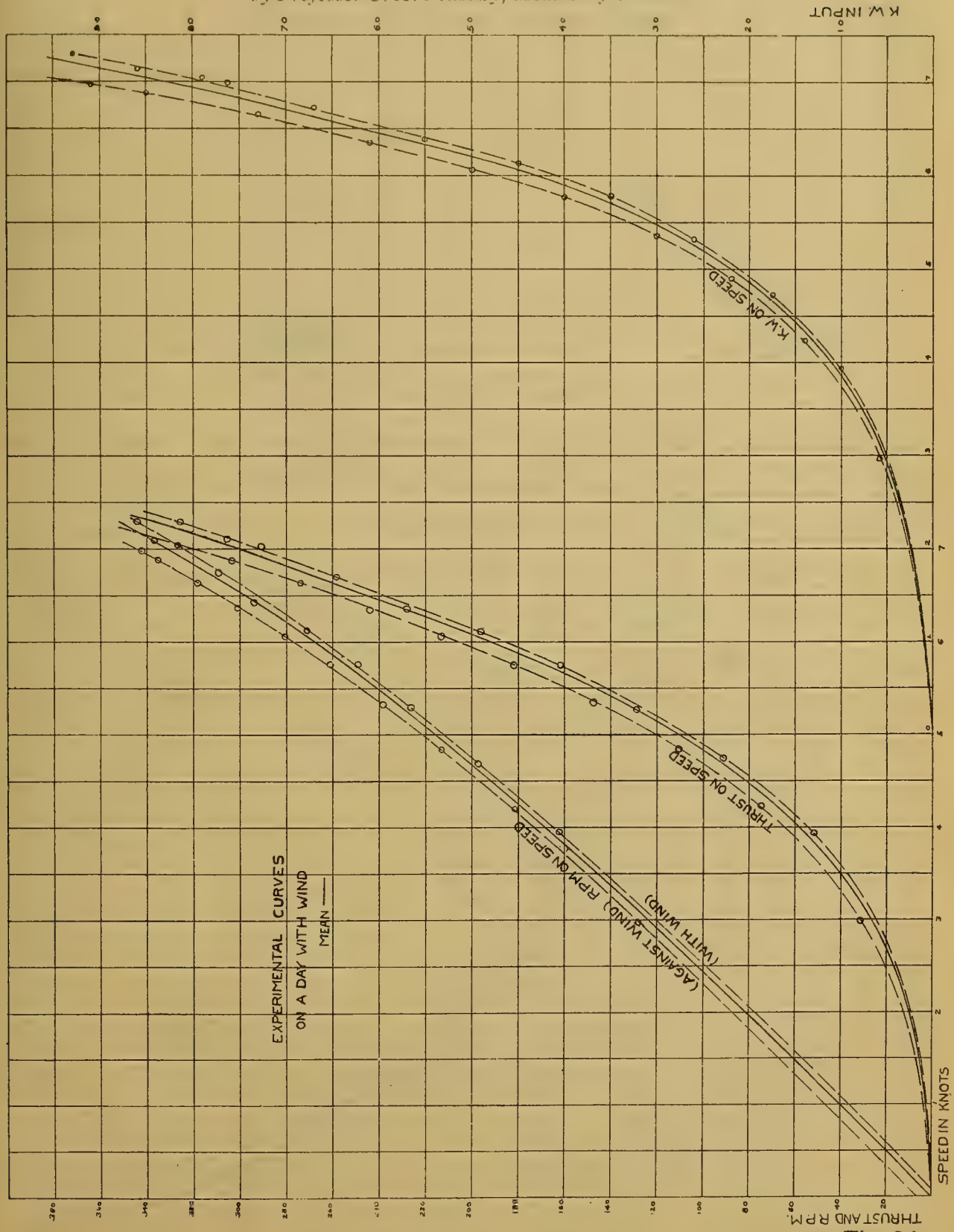

Fig. 24.

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

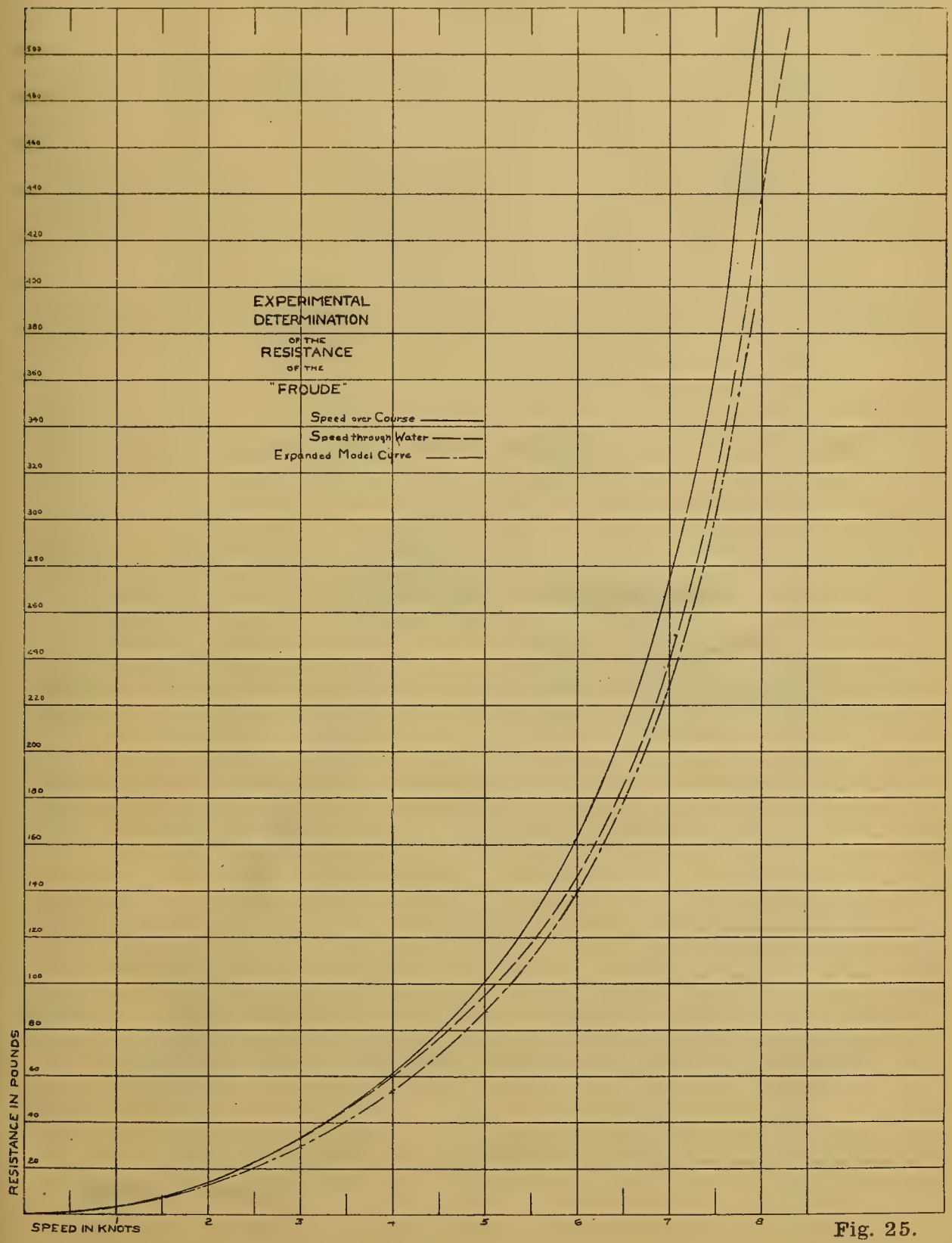

Fig. 25.

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To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

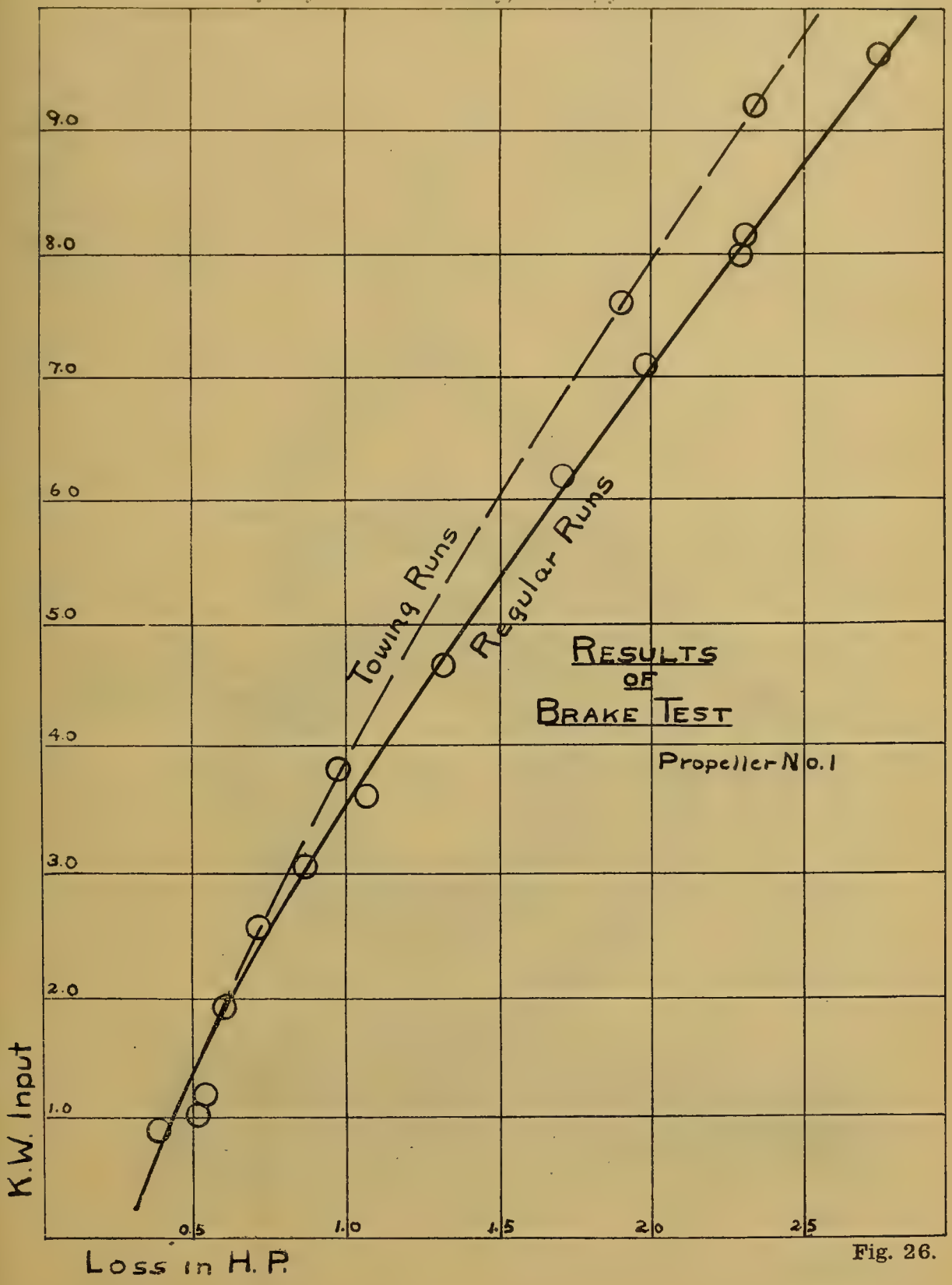

Fig. 26.

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To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

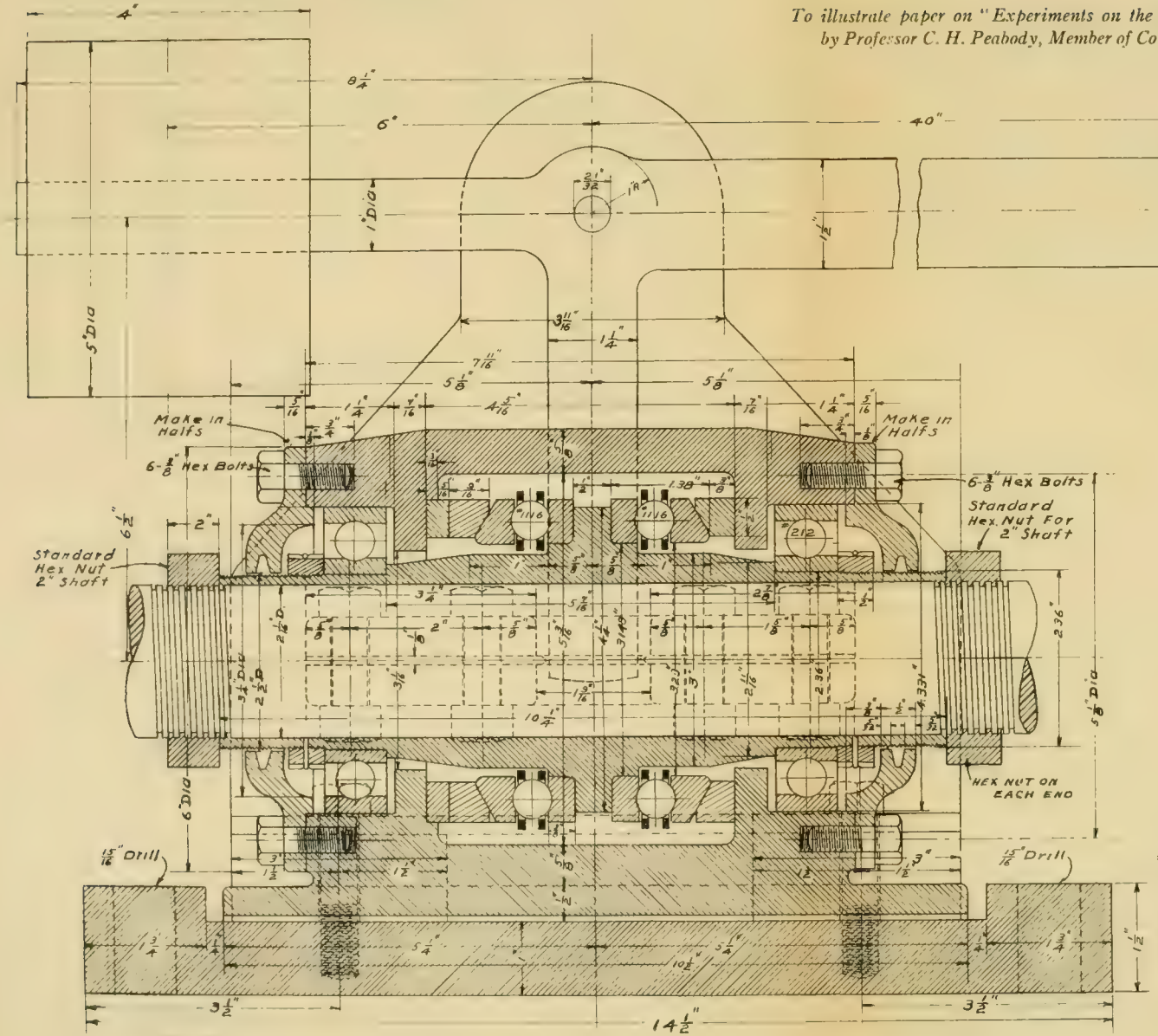


Fig. 27.

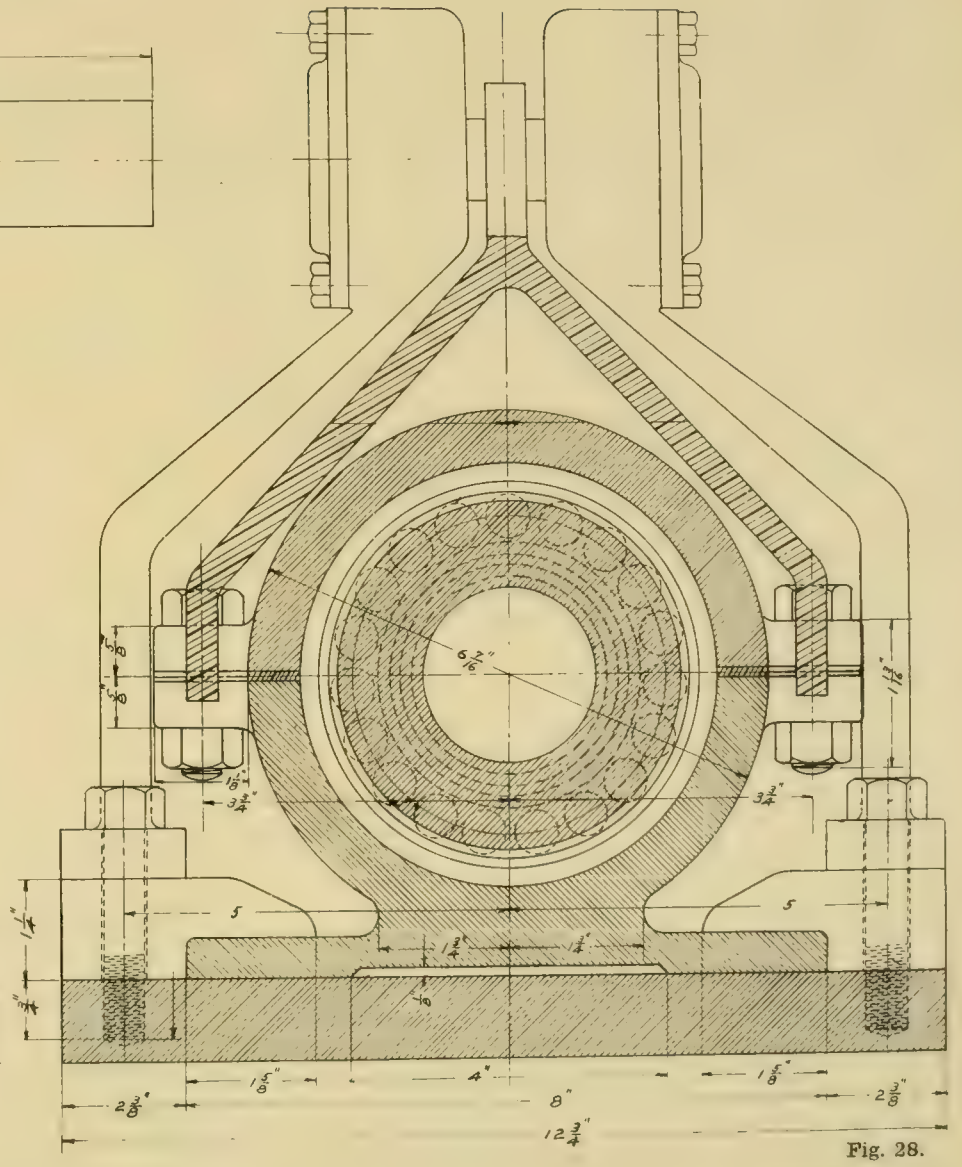


Fig. 28.

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.

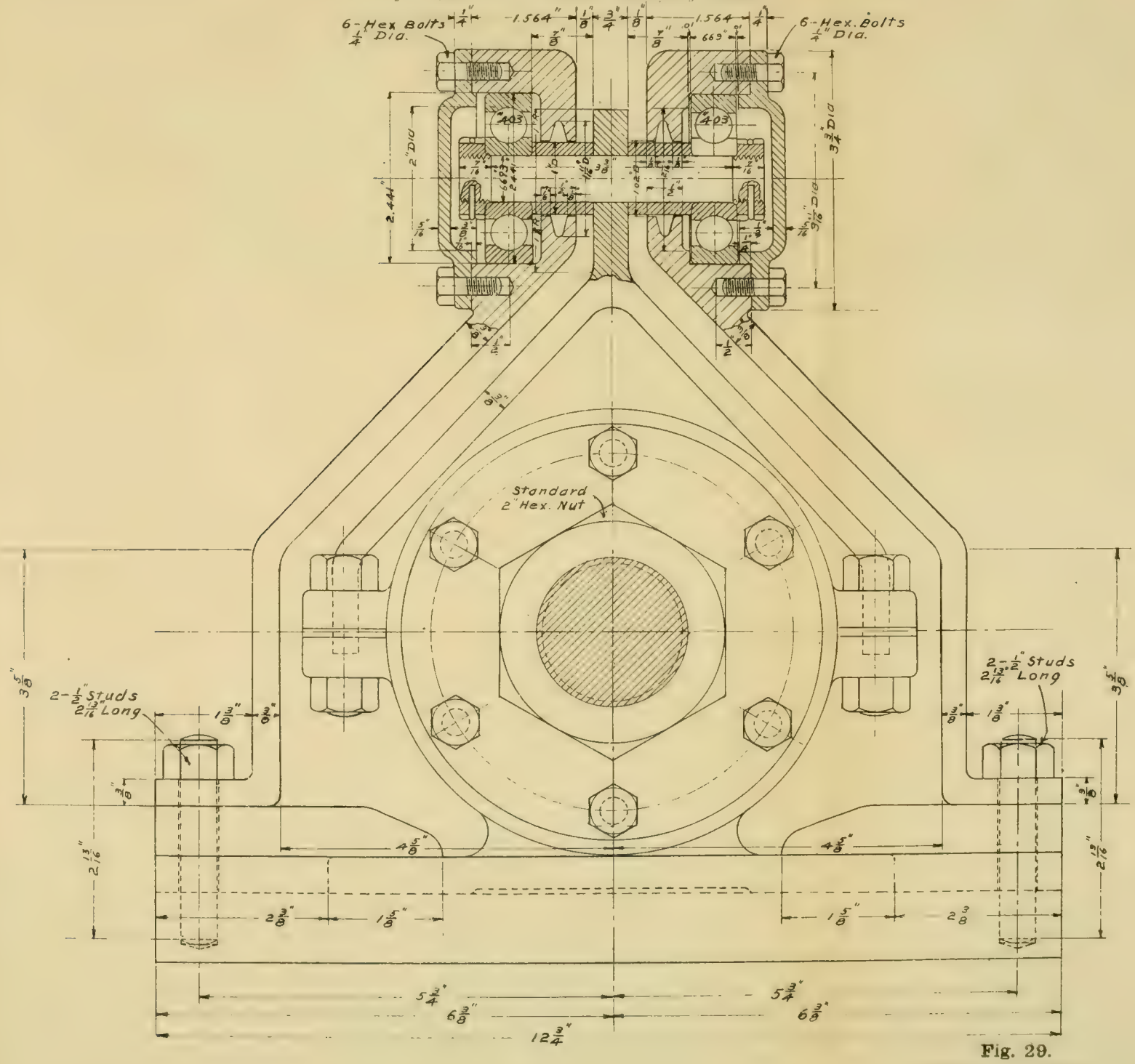
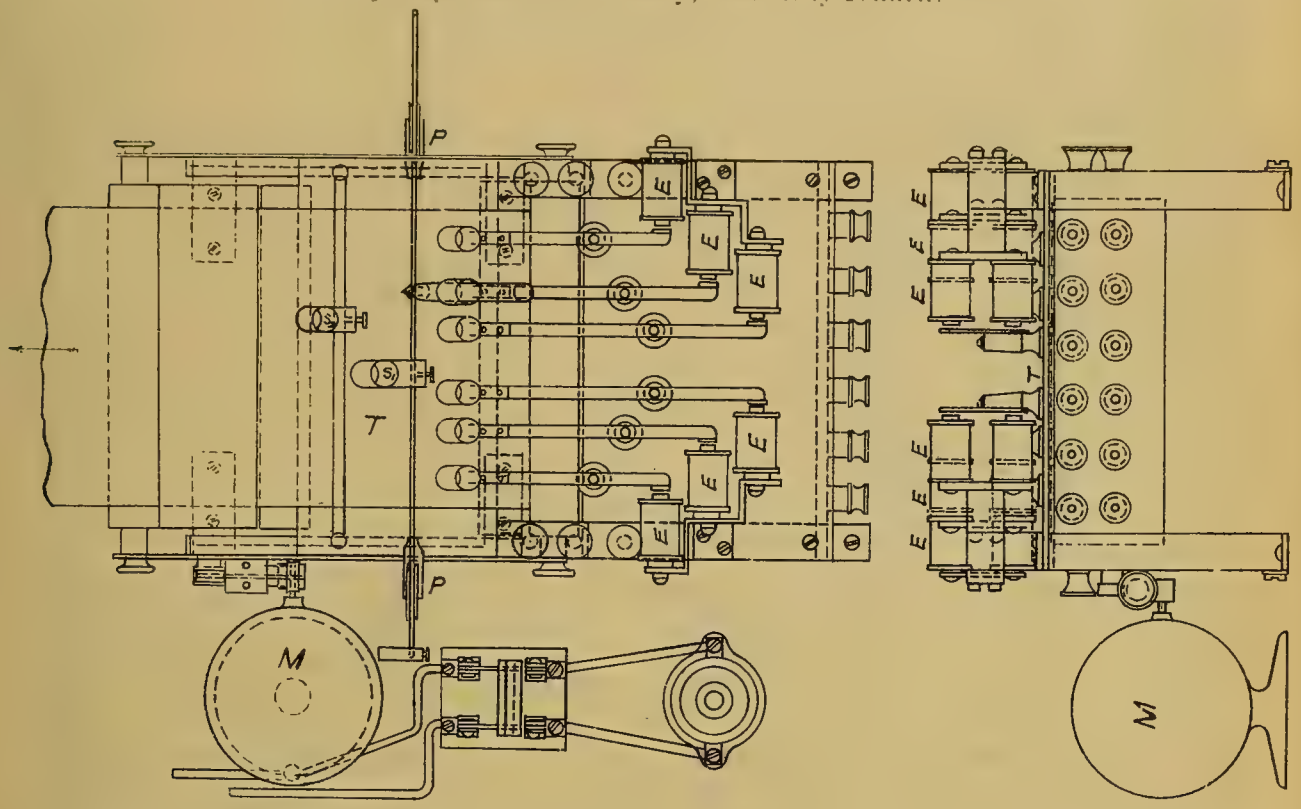


Fig. 29.

To illustrate paper on "Experiments on the Froude," by Professor C. H. Peabody, Member of Council.



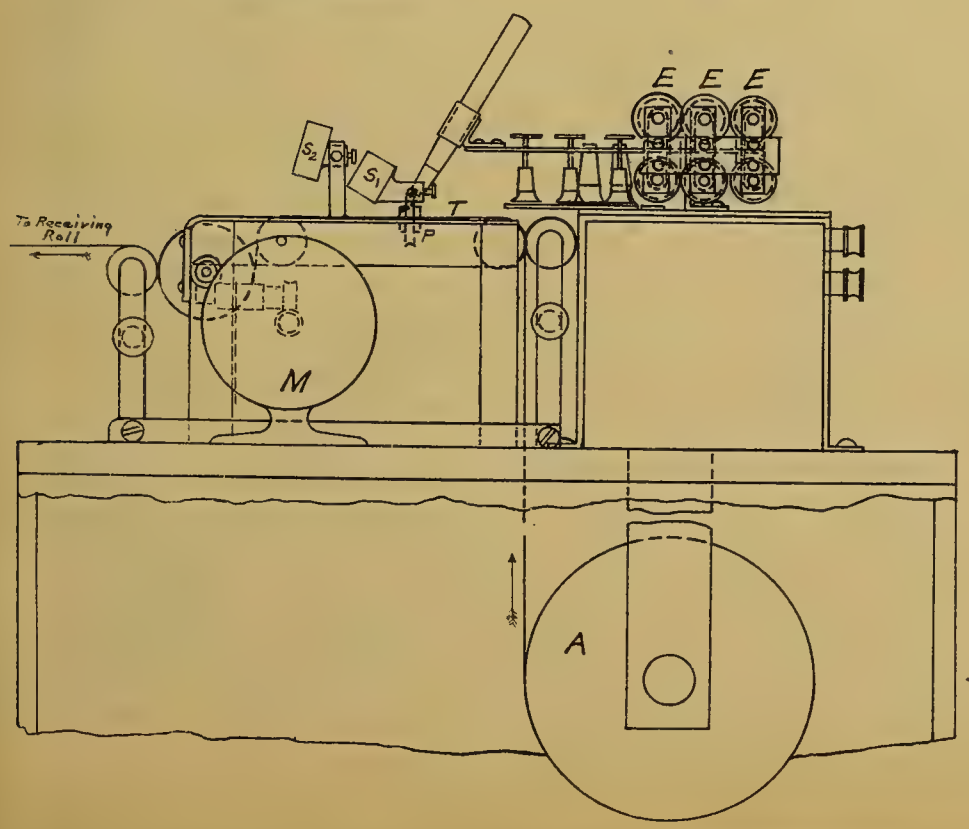
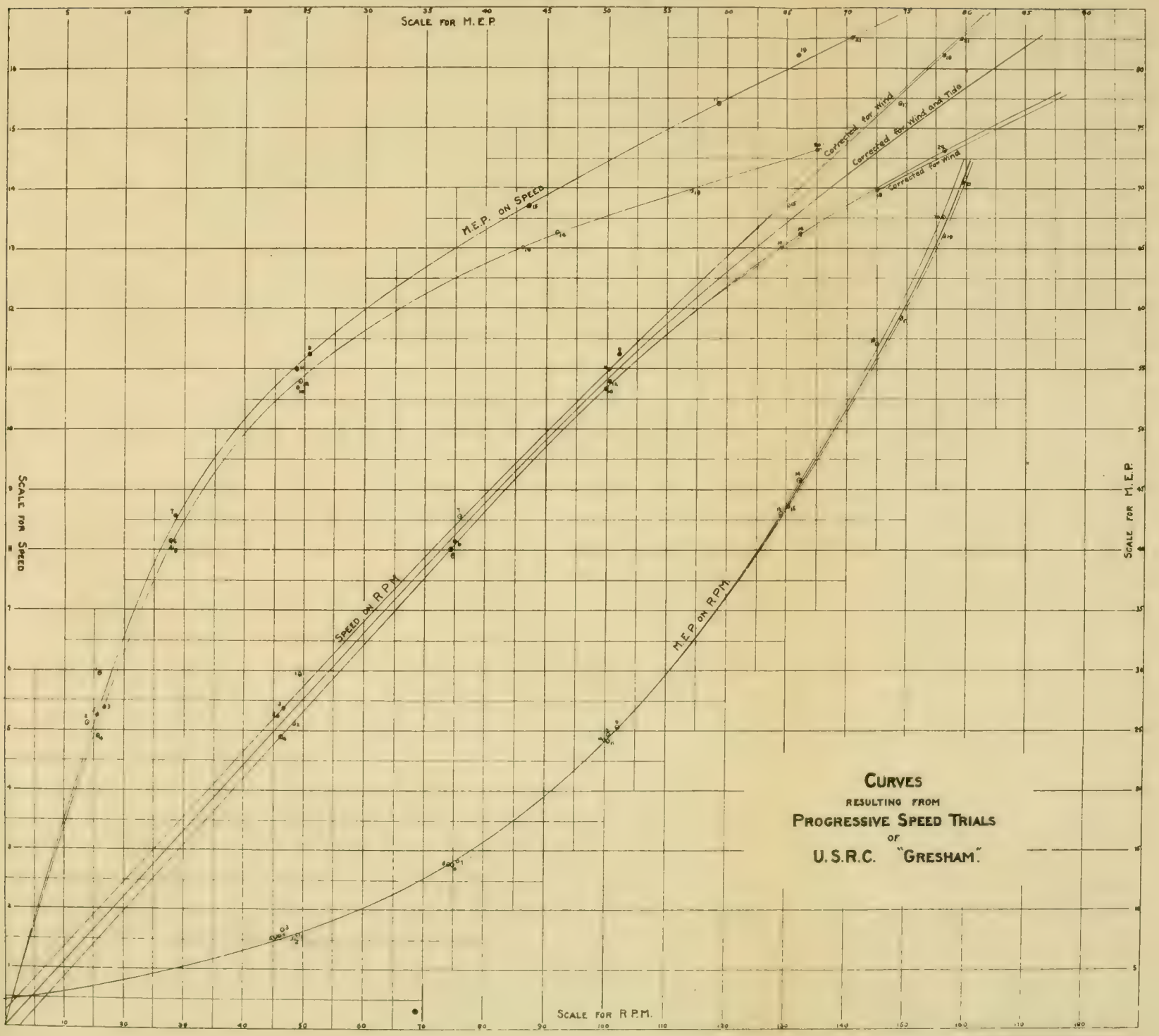


Fig. 30.

To illustrate paper on "The Effect of Waves upon a Taffrail Log," by Professor Harold A. Everett, Member.



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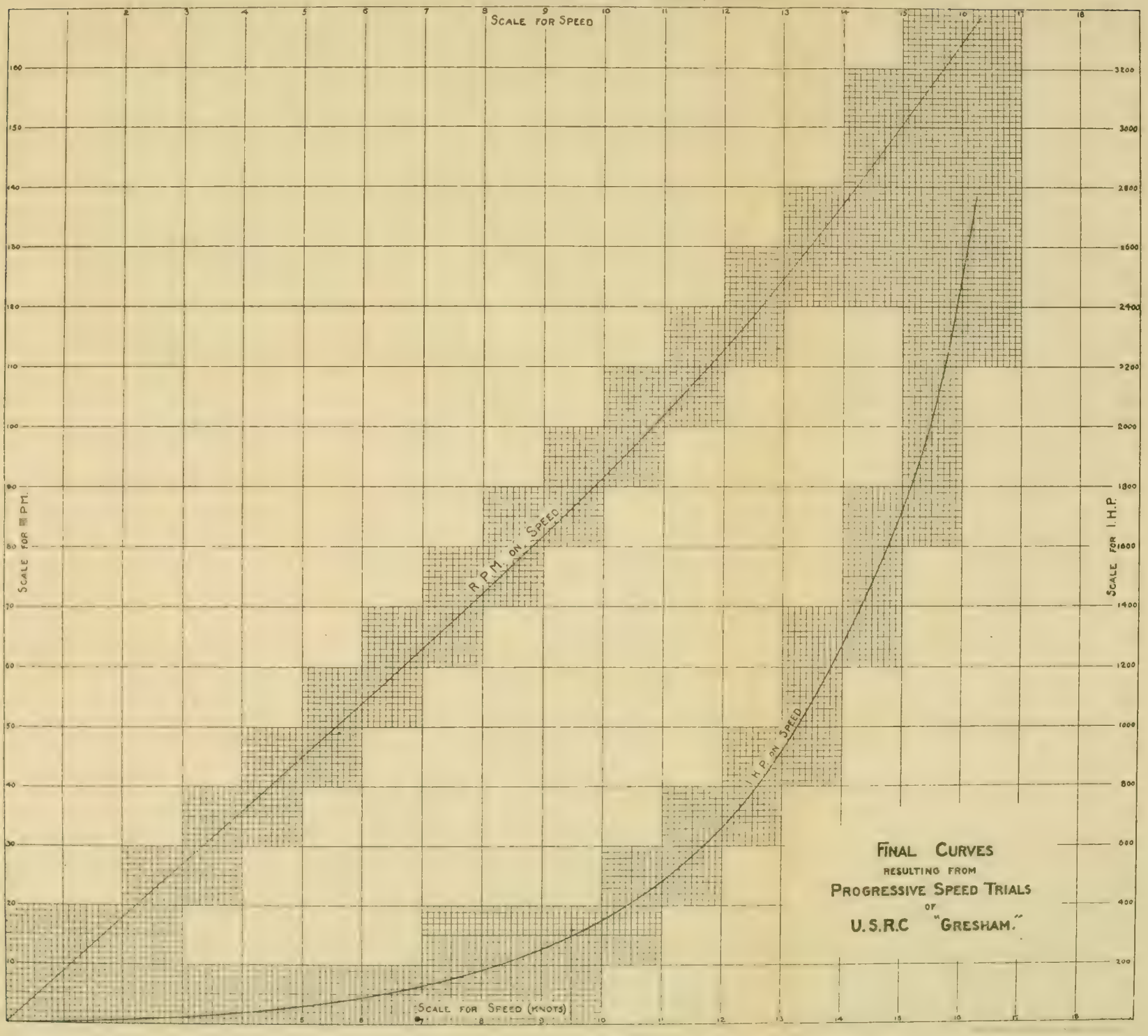

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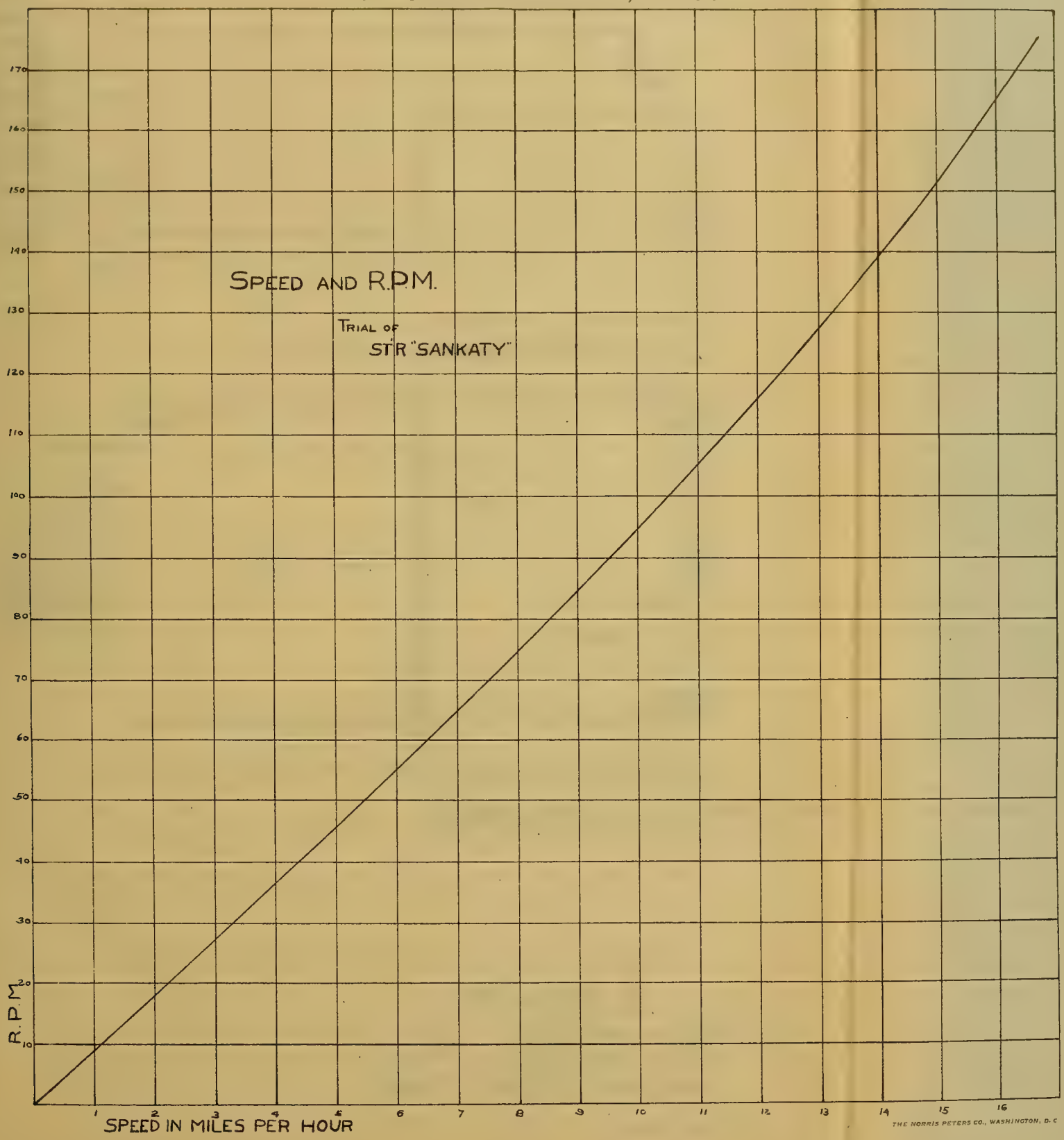


To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

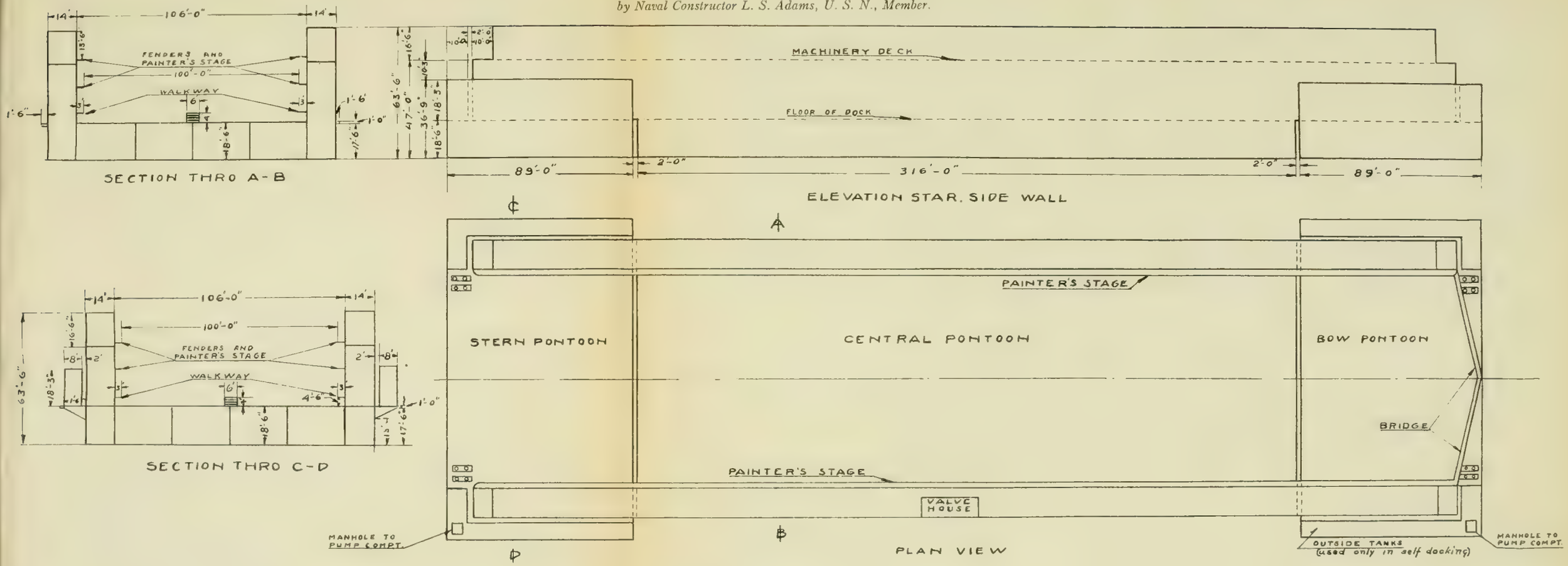


PLATE I.
PLAN AND ELEVATION OF DRY DOCK DEWEY

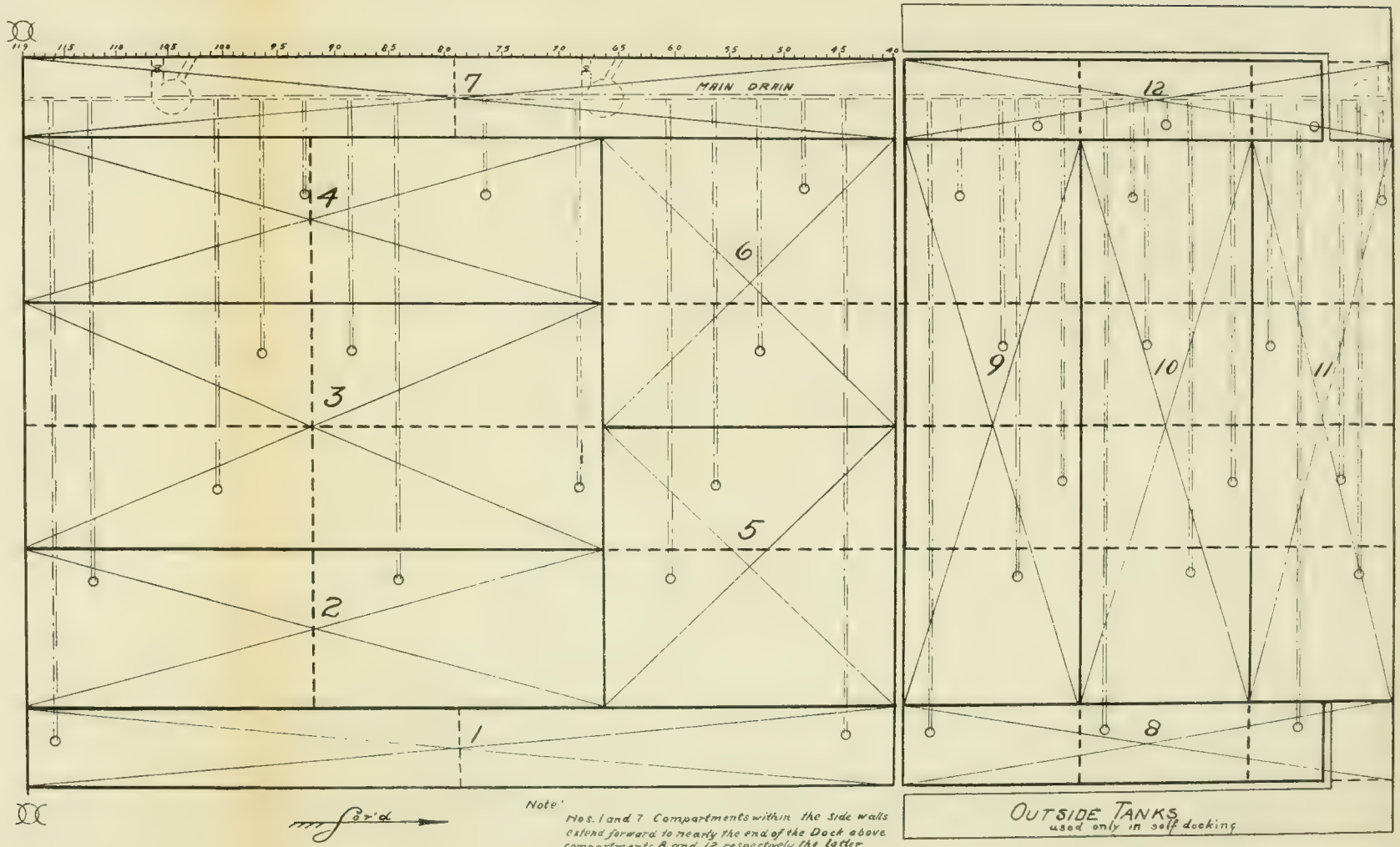
To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

PLATE II

DRY DOCK DEWEY
PLAN SHOWING ARRANGEMENT OF WATER TANKS AND THEIR CAPACITIES AND PUMPING AND FLOODING PIPING

MAIN COMPARTMENTS		
No.	TONS	SIZE
1	3834.4	(158'x47'x14') + (80'x14'x27')
2	1681.2	104'x30 7/12'x18½'
3	2473.7	104'x45'x18½'
4	1681.2	104'x30 7/12'x18½'
5	1512.8	54'x53'x18½'
6	1512.8	54'x53'x18½'
7	3834.4	(158'x47'x14') + (80'x14'x27')
8	658.6	89'x14'x18½'
9	1792.9	32'x106'x18½'
10	1792.9	32'x106'x18½'
11	1400.7	25'x106'x18½'
12	658.6	89'x14'x18½'

NOTE:
BROKEN LINES SHOW WATER TIGHT SUBDIVISIONS OF MAIN COMPARTMENTS. ALL VALVES IN EACH MAIN COMPARTMENT ARE OPERATED BY ONE LEVER



Note:
Nos. 1 and 7 Compartments within the side walls extend forward to nearly the end of the Dock above compartments 8 and 12 respectively the latter are bottom tanks only

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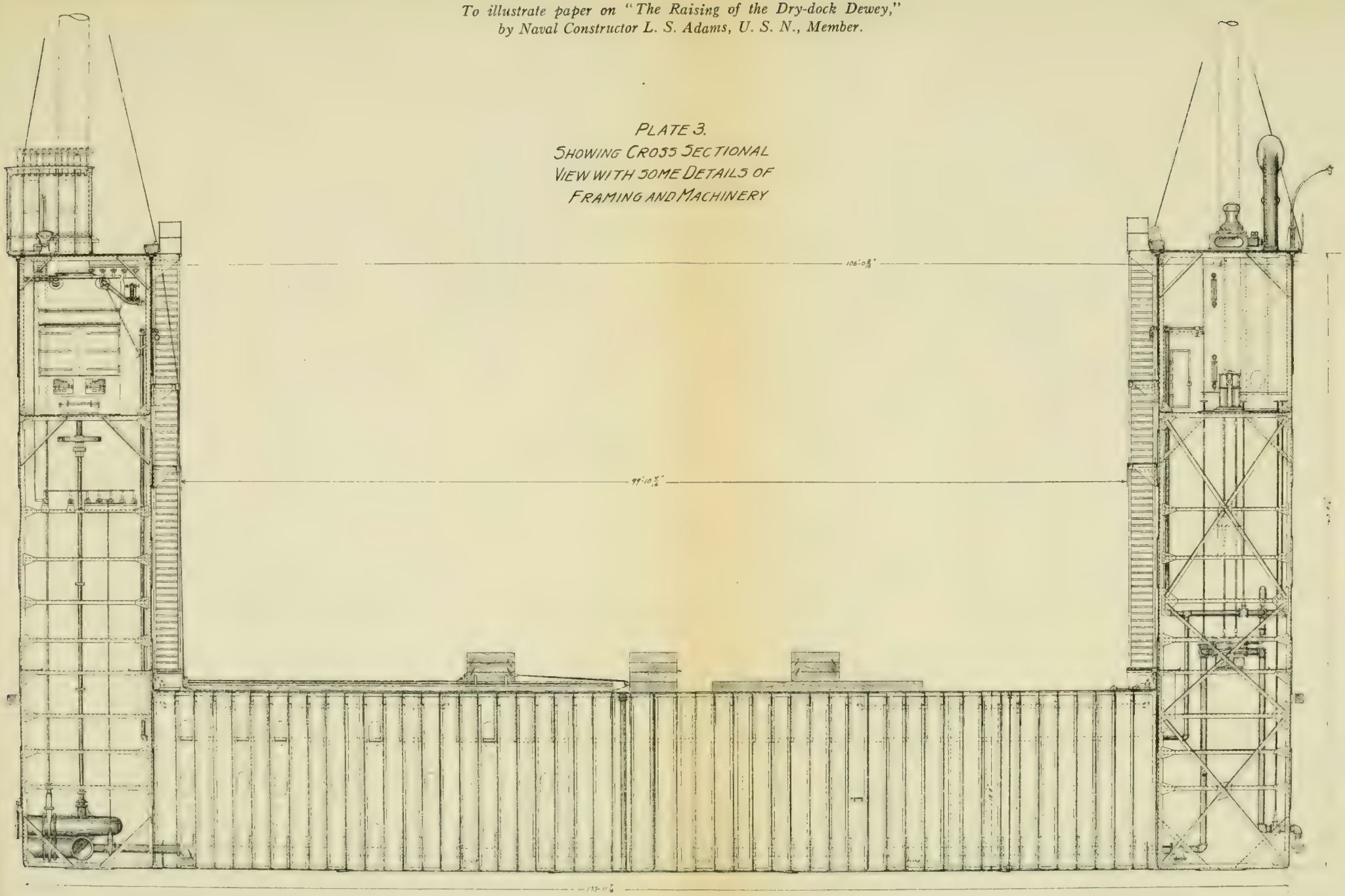
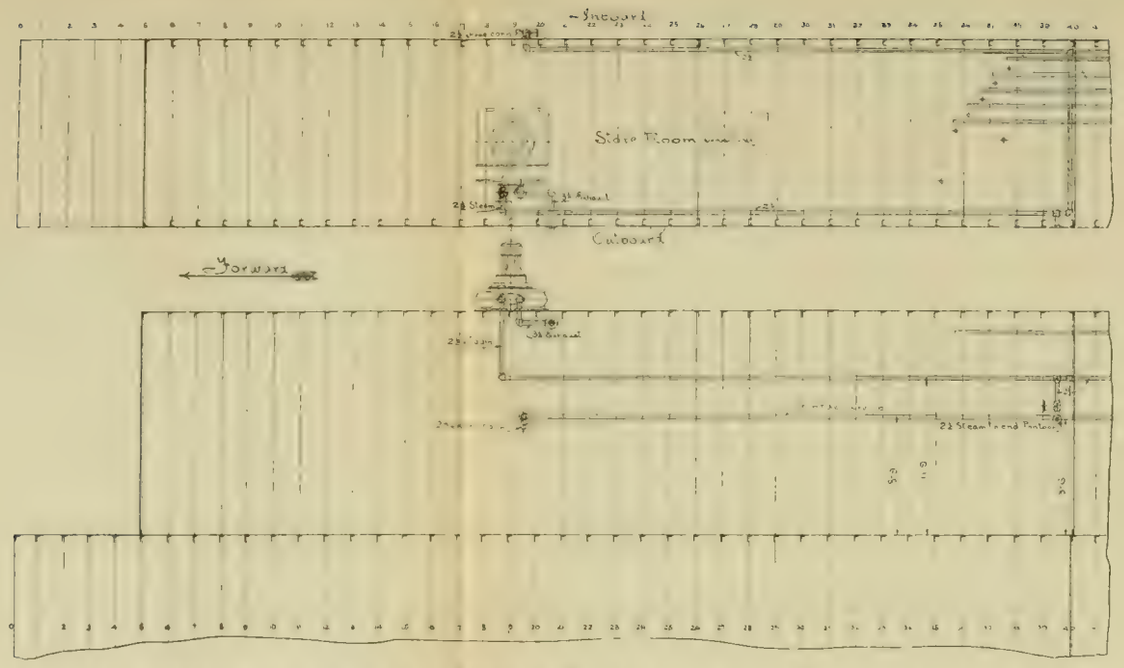
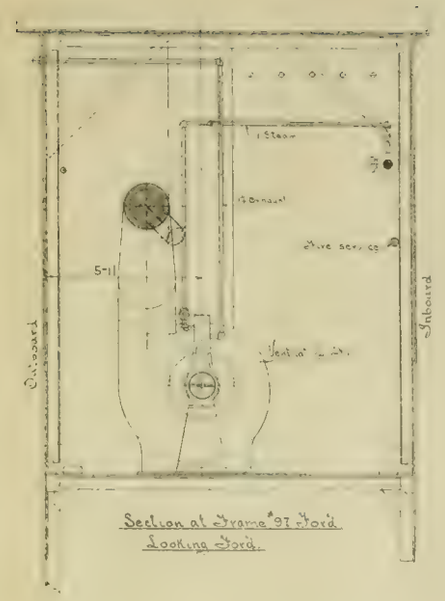
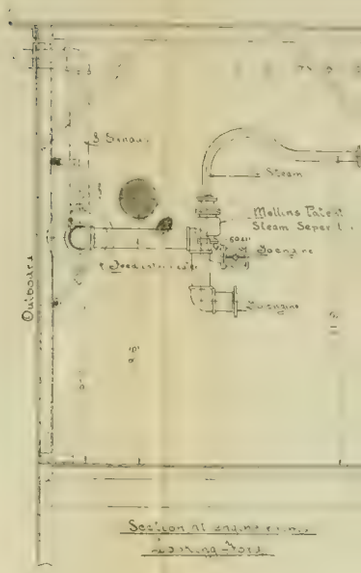
To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

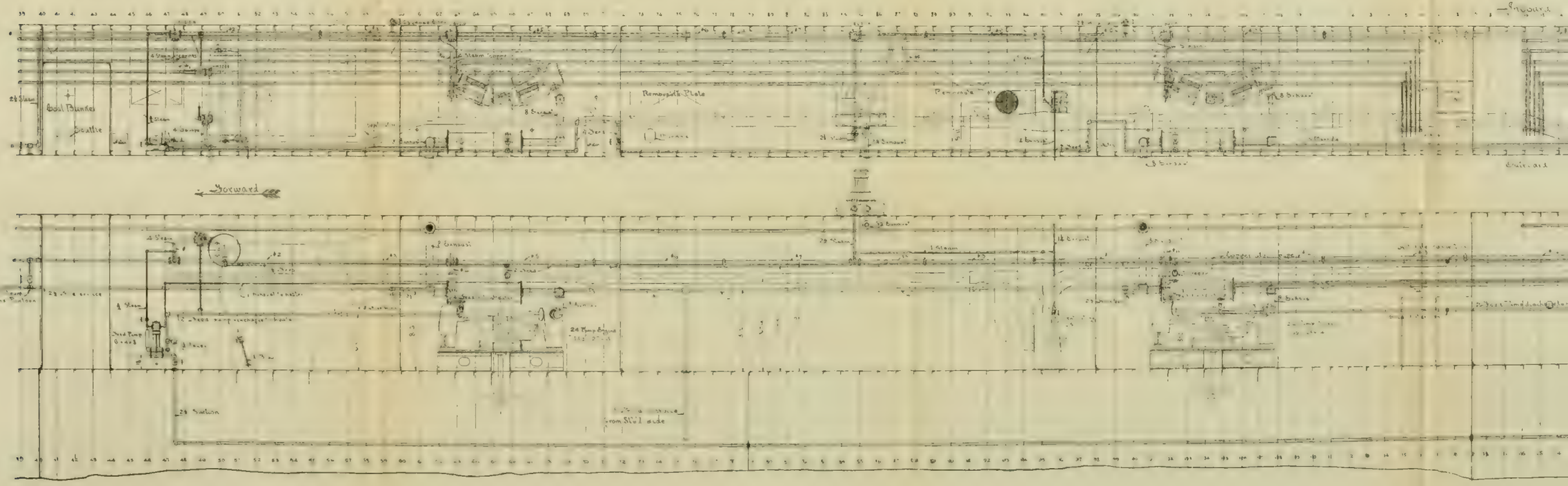


To illustrate paper on "The Raising of the Dry-
by Naval Constructor L. S. Adams, U. S. N.,









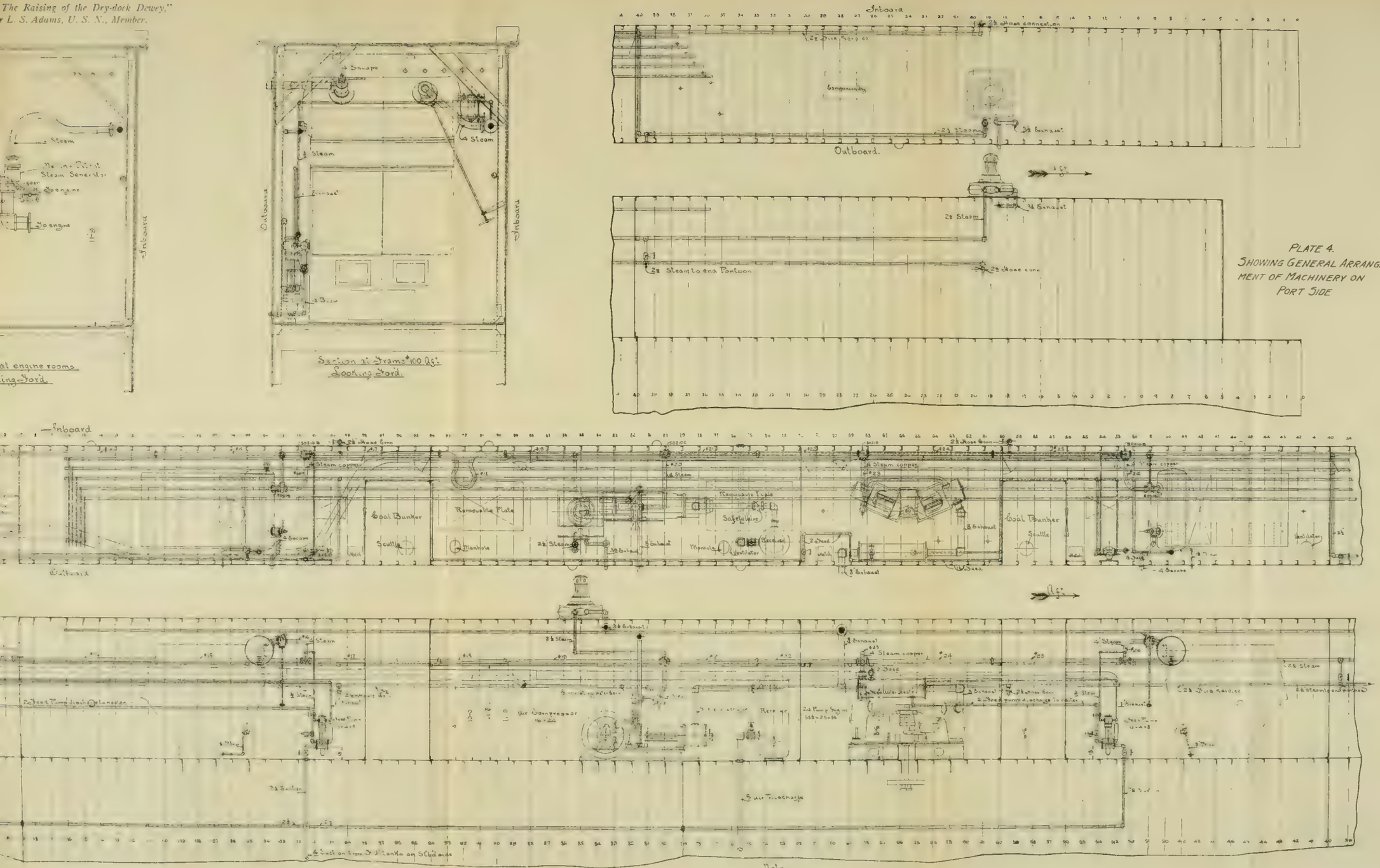


PLATE 4.
SHOWING GENERAL ARRANGEMENT OF MACHINERY ON PORT SIDE

To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

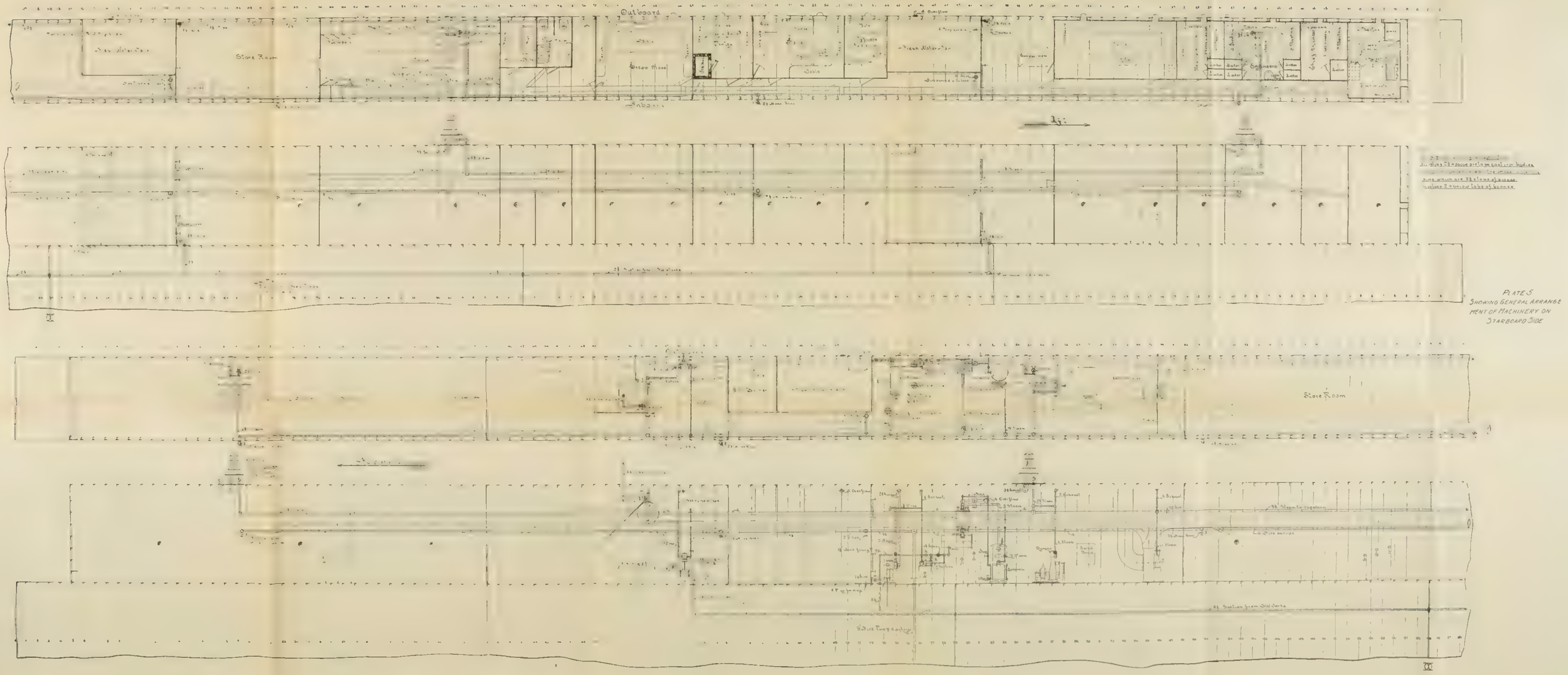


PLATE 5
SHOWING GENERAL ARRANGEMENT OF MACHINERY ON STARBOARD SIDE

To illustrate paper on "The Raising of the Dry-dock Dewey,
by Naval Constructor L. S. Adams, U. S. N., Member

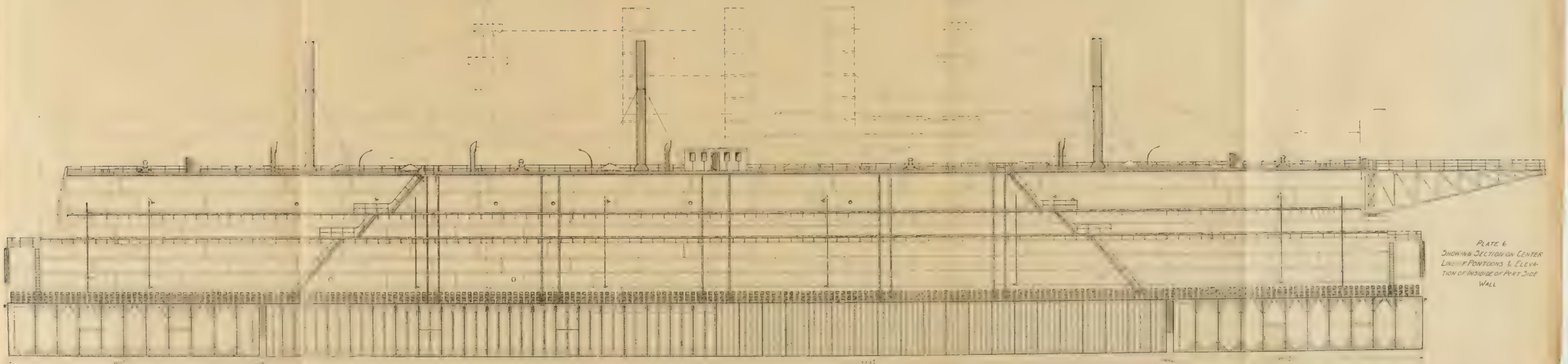


PLATE 6
SHOWING SECTION ON CENTER LINE OF PONTOONS & ELEVATION OF INSIDE OF PORT SIDE WALL

To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member

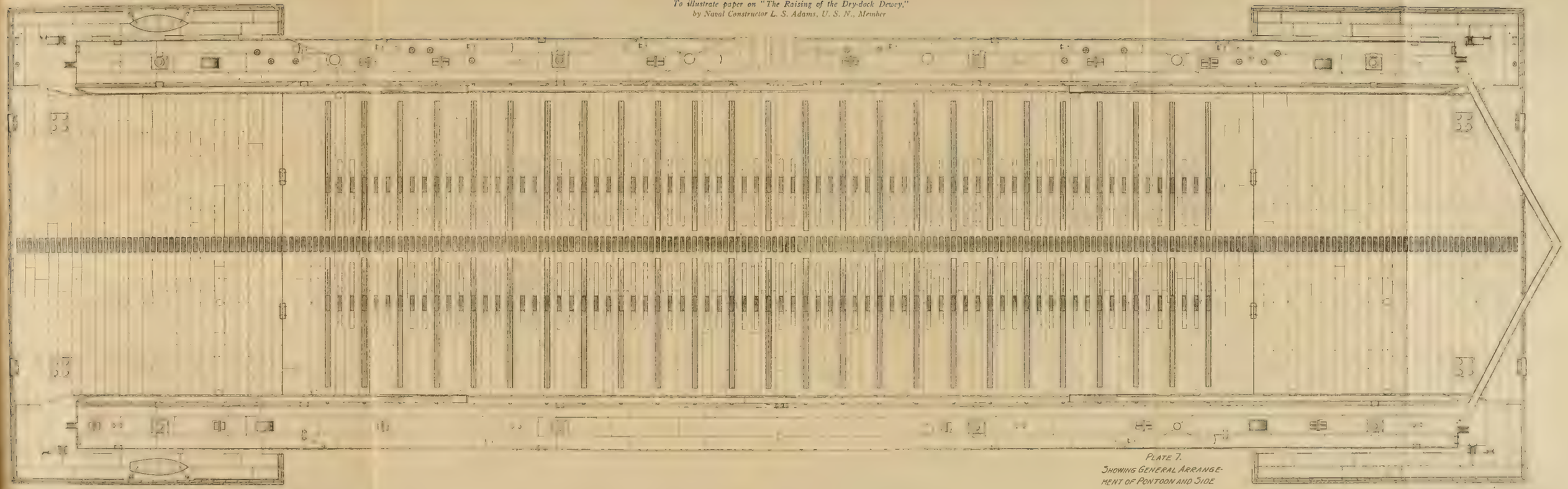


PLATE 7.
SHOWING GENERAL ARRANGEMENT OF PONTOON AND SIDE WALL DECKS

To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

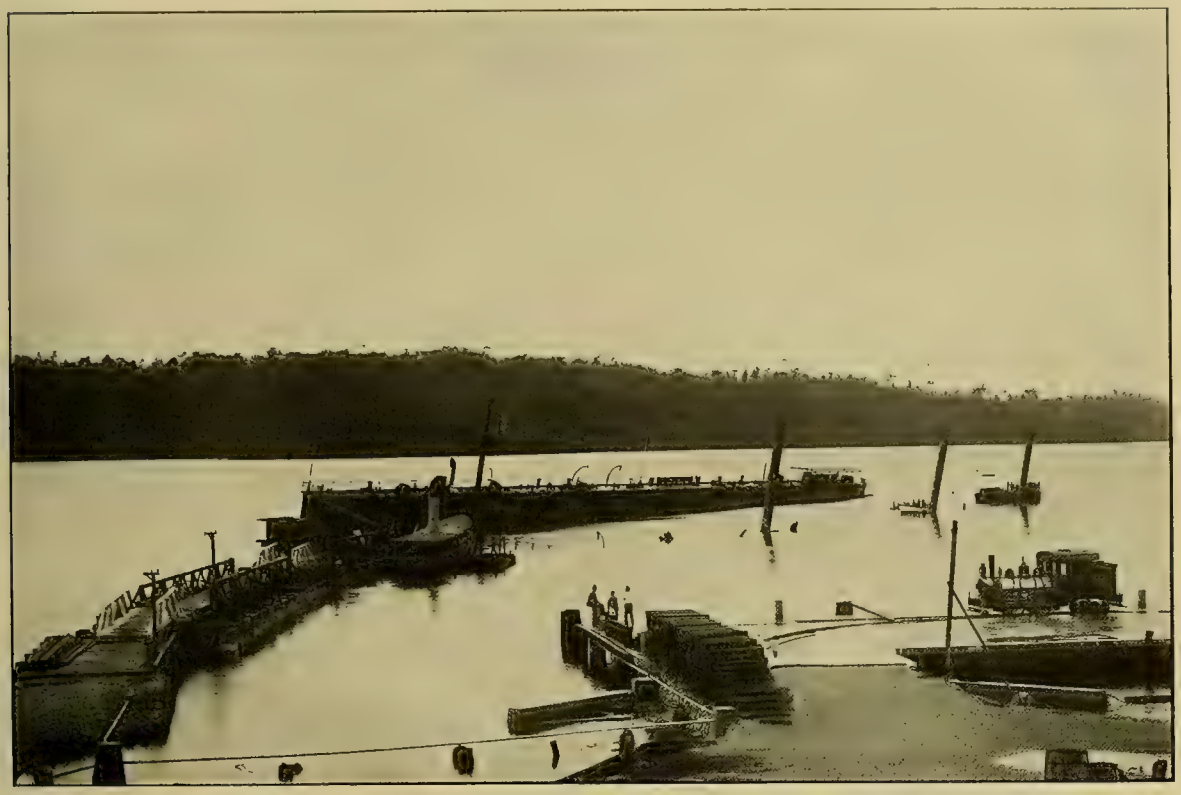


FIG. 1.—DRY-DOCK DEWEY FROM SOUTH GATE. MAY 24, 1910, 10.20 A. M. TIDE 4.5.

FIG. 2.—DRY-DOCK DEWEY FROM SOUTH GATE. MAY 26, 1910, 9.20 A. M. TIDE 4.5.

To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

FIG. 1.—DRY-DOCK DEWEY FROM SOUTH GATE. JUNE 10, 1910, 3.30 P. M. TIDE 2.1.

FIG. 2.—DRY-DOCK DEWEY FROM SOUTH GATE. JUNE 14, 1910, 5.15 P. M. TIDE 3.5.

To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

FIG. 1.—DRY-DOCK DEWEY FROM SOUTH GATE. JUNE 15, 1910, 10.45 A. M. TIDE 3.5.

FIG. 2.—DRY-DOCK DEWEY FROM QUAY WALL. JUNE 15, 1910, 1.35 P. M. TIDE 4.2.

To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

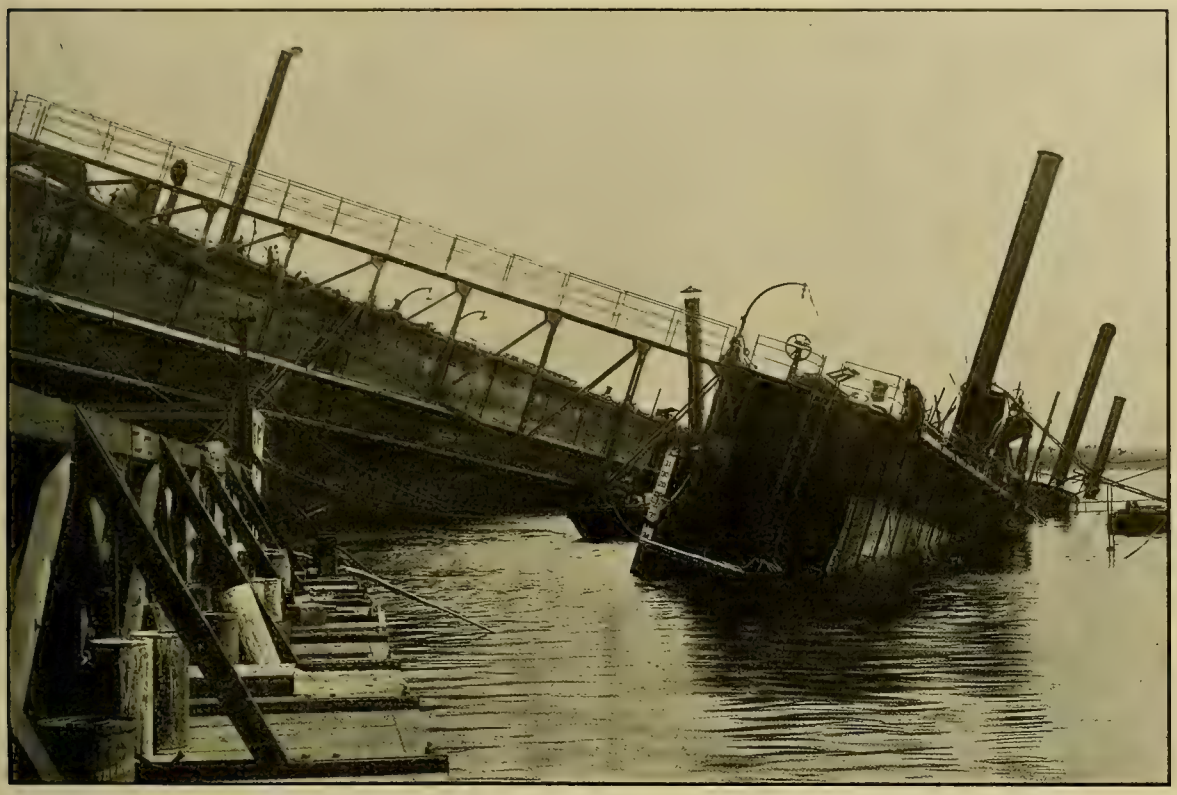


FIG. 1.—DRY-DOCK DEWEY FROM PONTOON APPROACH. JUNE 15, 1910, 1.50 P. M. TIDE 4.3.

FIG. 2.—DRY-DOCK DEWEY FROM LIGHTER. JUNE 15, 1910, 2.05 P. M. TIDE 4.3.

To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

FIG. 1.—DRY-DOCK, LOOKING AFT FROM BRIDGE. JUNE 29, 1910, 8.20 A. M.

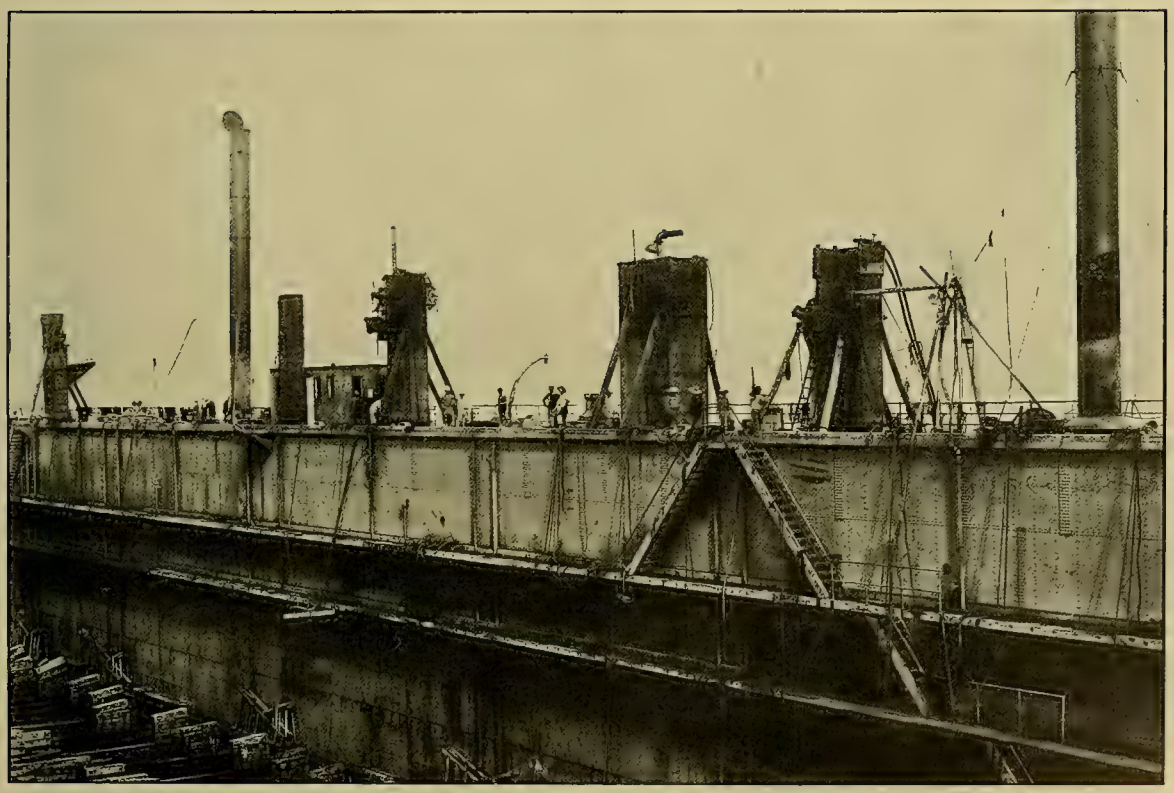


FIG. 2.—DRY-DOCK, PORT SIDE, LOOKING AFT. JUNE 29, 1910, 8.30 A. M.

To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

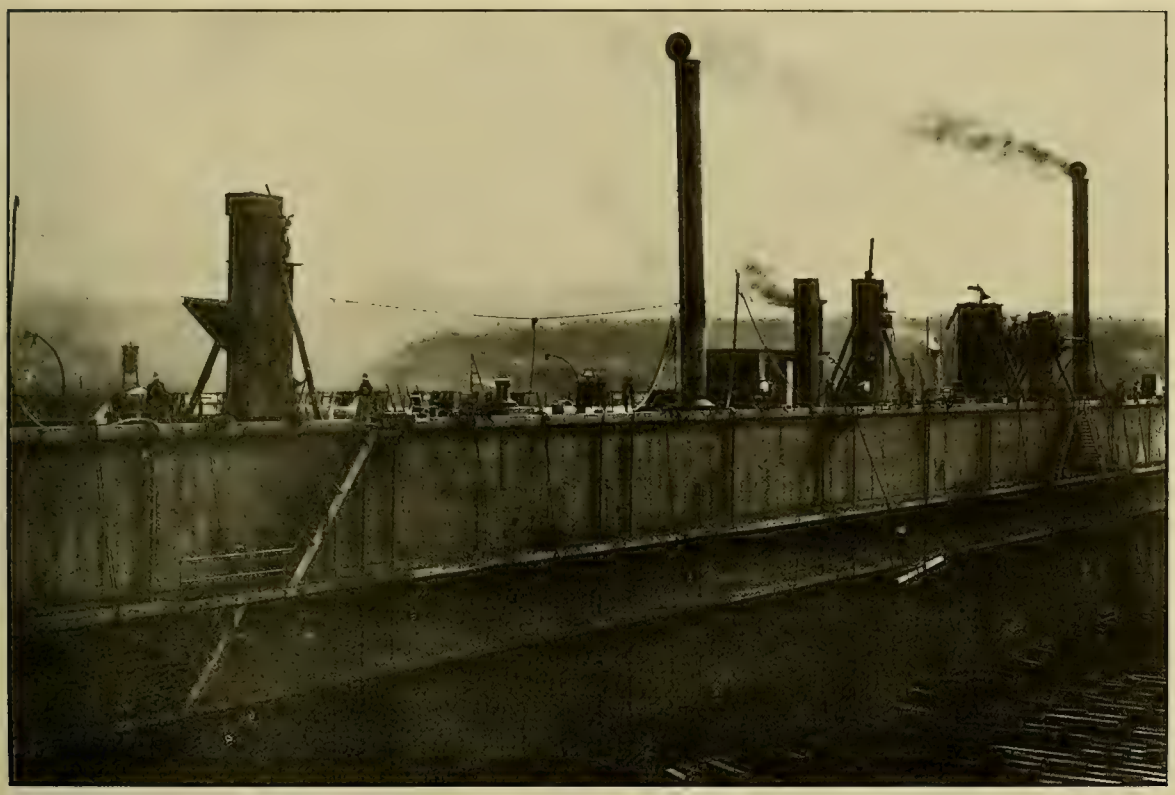


FIG. 1.—DRY-DOCK, PORT SIDE, LOOKING FORWARD. JUNE 29, 1910, 8.45 A. M.

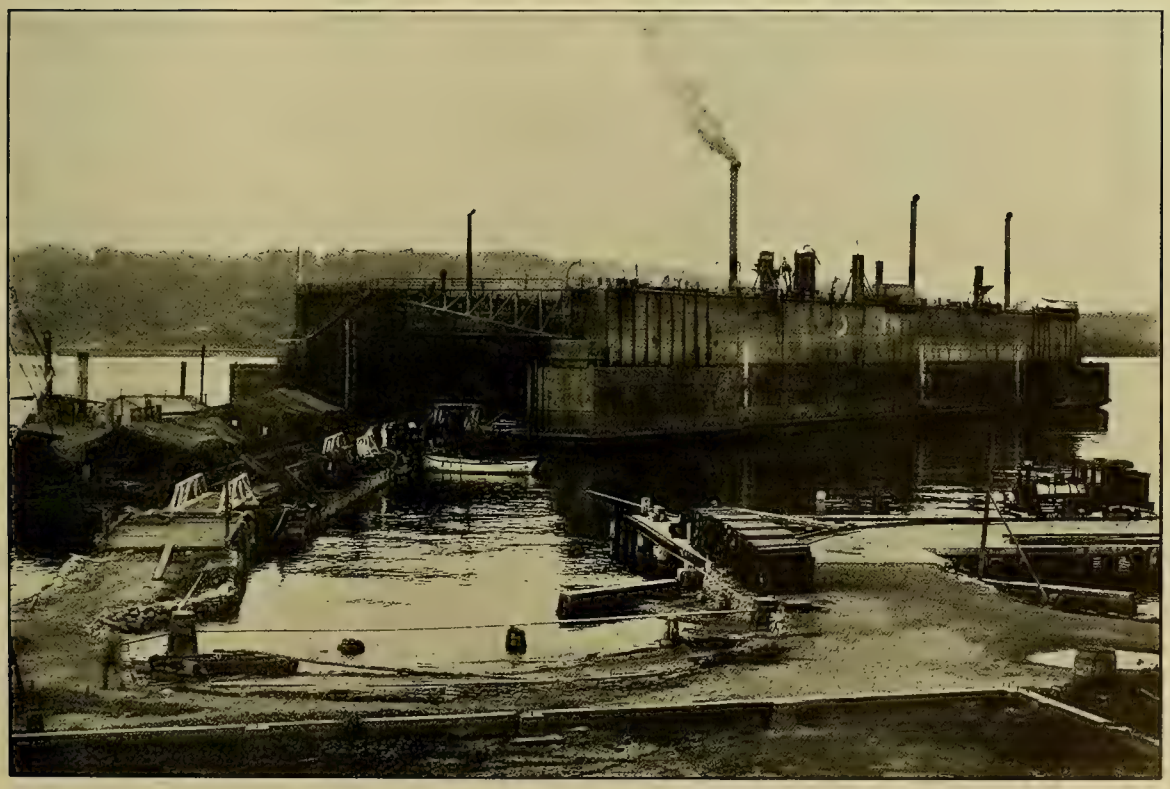


FIG. 2.—DRY-DOCK FROM SOUTH GATE. JUNE 29, 1910, 10.10 A. M.

To illustrate paper on "The Raising of the Dry-dock Dewey," by Naval Constructor L. S. Adams, U. S. N., Member.

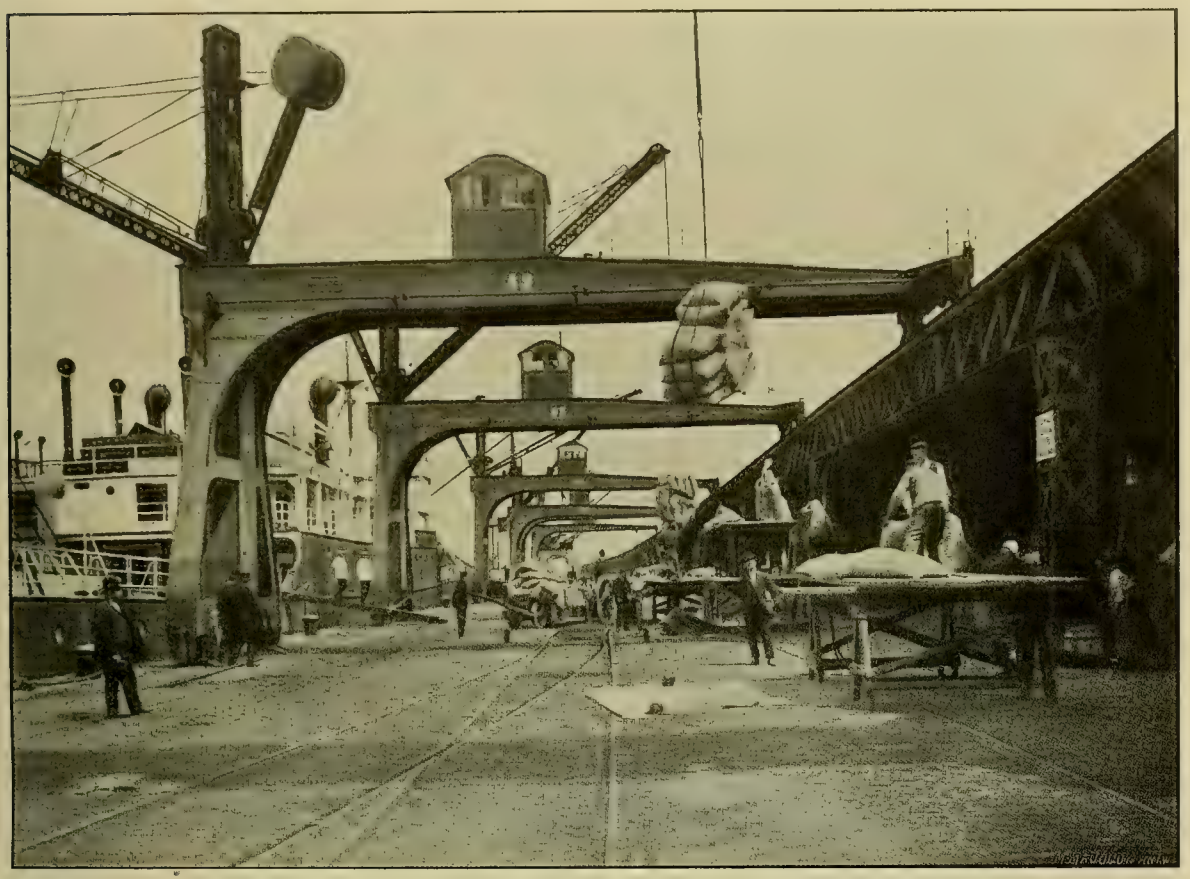
Naval Constructor L. S. ADAMS, U. S. N. (in white helmet) in charge of the work; Gunner SAMONSKI, U. S. N., and the enlisted divers who did the bulk of the diving work, some of it being of a most difficult character in depths up to eighty feet. This photograph shows also a closer view of one of the steel cofferdams and the wood cofferdam over the valve house door.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.

INTERIOR OF PIER 37, NORTH RIVER, N. Y.

Cases piled or tiered to economical height; called by superintendent "A Full Pier." By higher tiering by mechanical methods the pier capacity could be doubled.

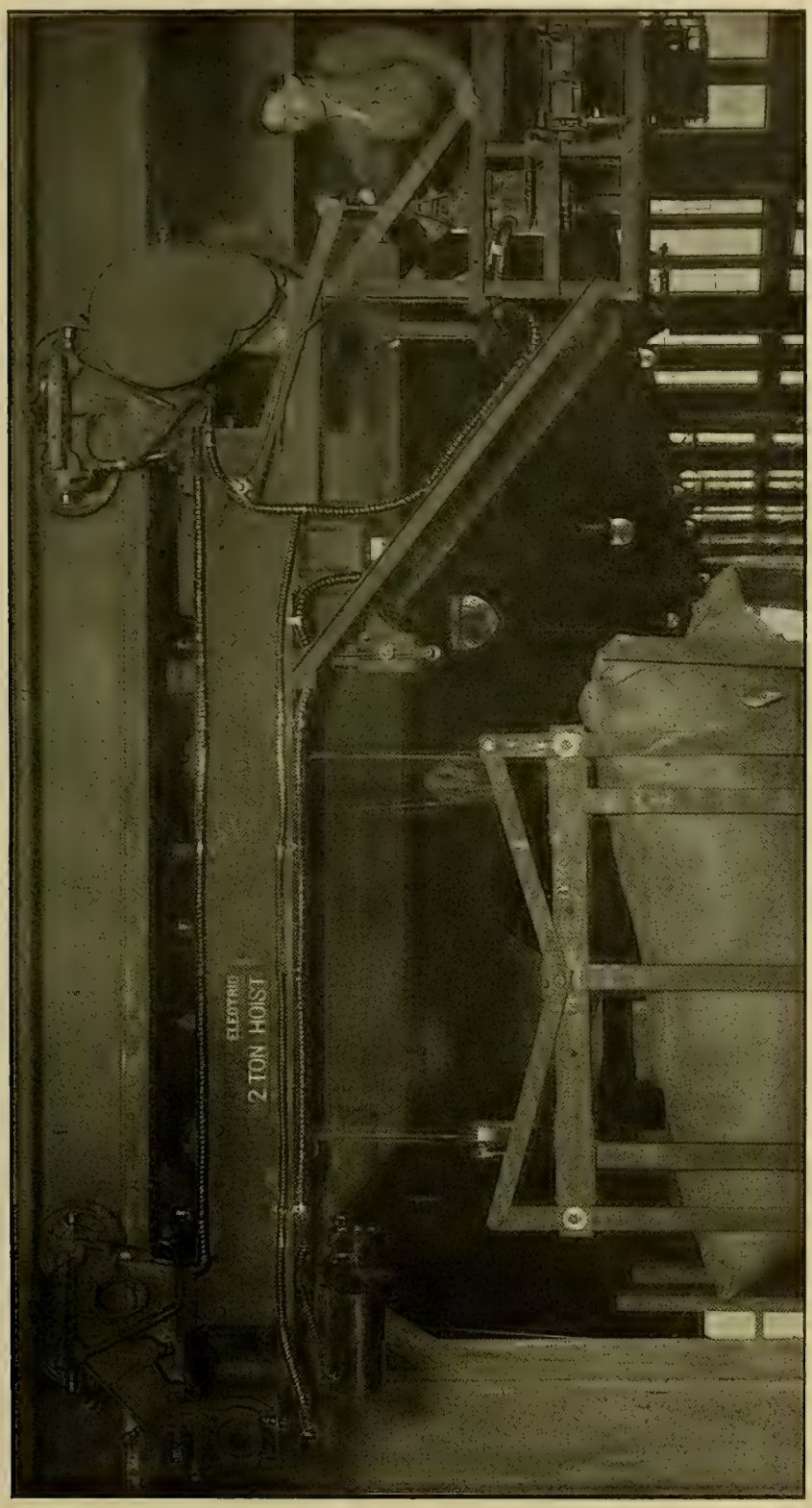
To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



ANTWERP.—HALF ARCH GANTRY CRANES. REHANDLING NECESSARY.

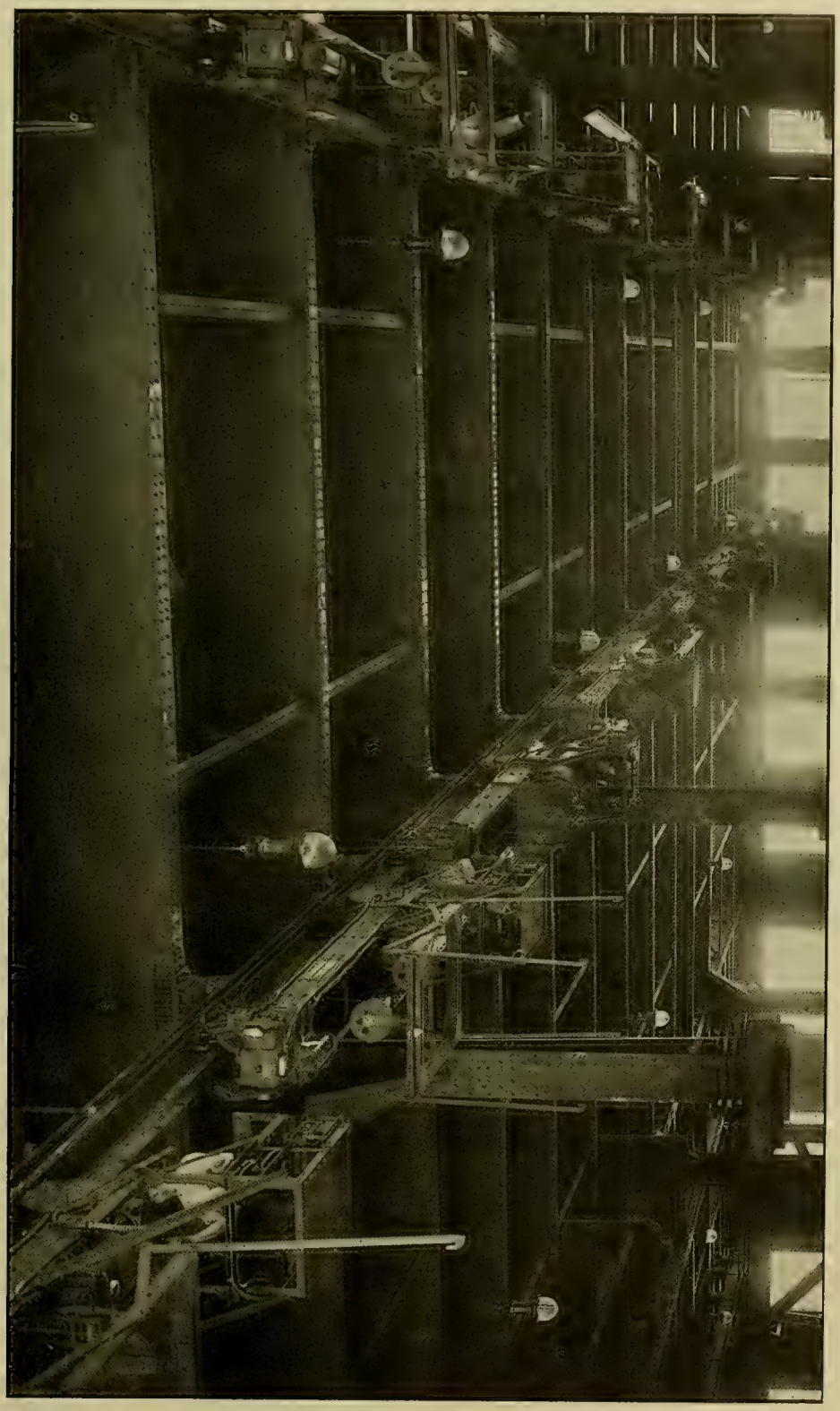
ANTWERP.—FULL ARCH GANTRY CRANES. OPEN SHEDS.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



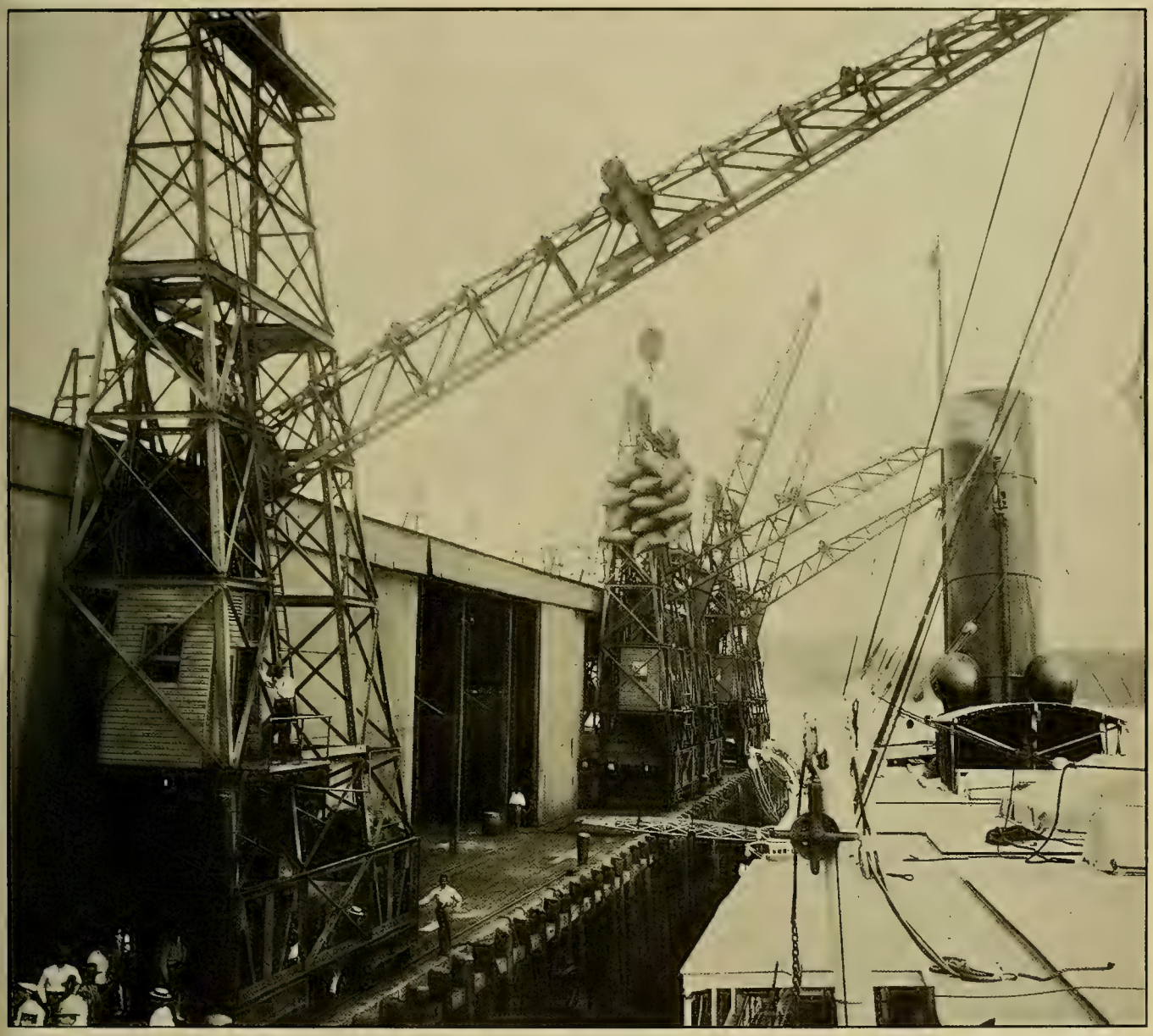
New Freight Station of the Missouri, Kansas & Texas R. R. Co. Transporting and Hoisting Mechanism.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



TWENTY TRAVELING HOISTS WITH OPERATORS.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



PRESENT TYPE OF CARGO HANDLING CRANES AT THE PACIFIC TERMINAL ON THE PANAMA RAILWAY.

They make on the average, a complete cycle in three minutes, but the average discharging of each crane is between 25 and 30 tons per hour, due to the average weight of the loads being only one and one-half tons.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.

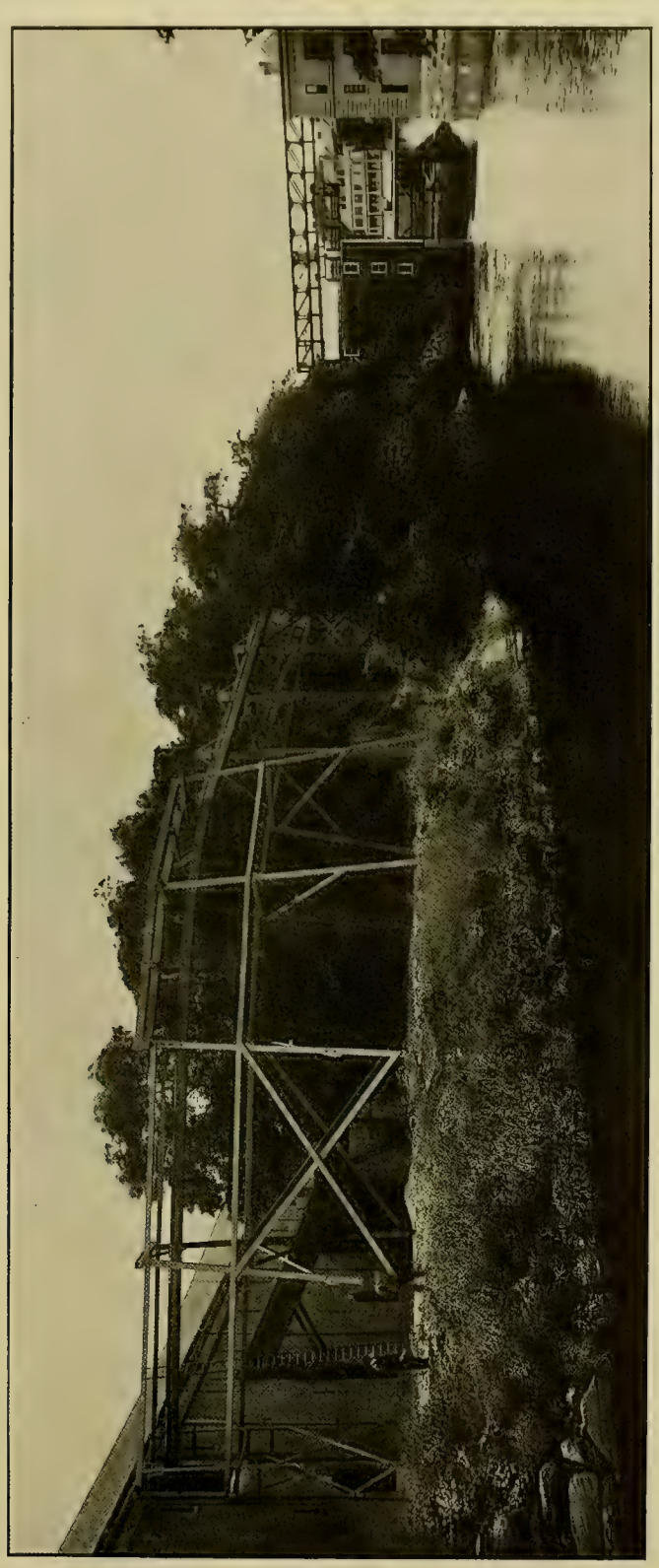
Locomotive Crane in Freight Transference between Car and Lighter.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.

Storage Battery Truck with Trailers.

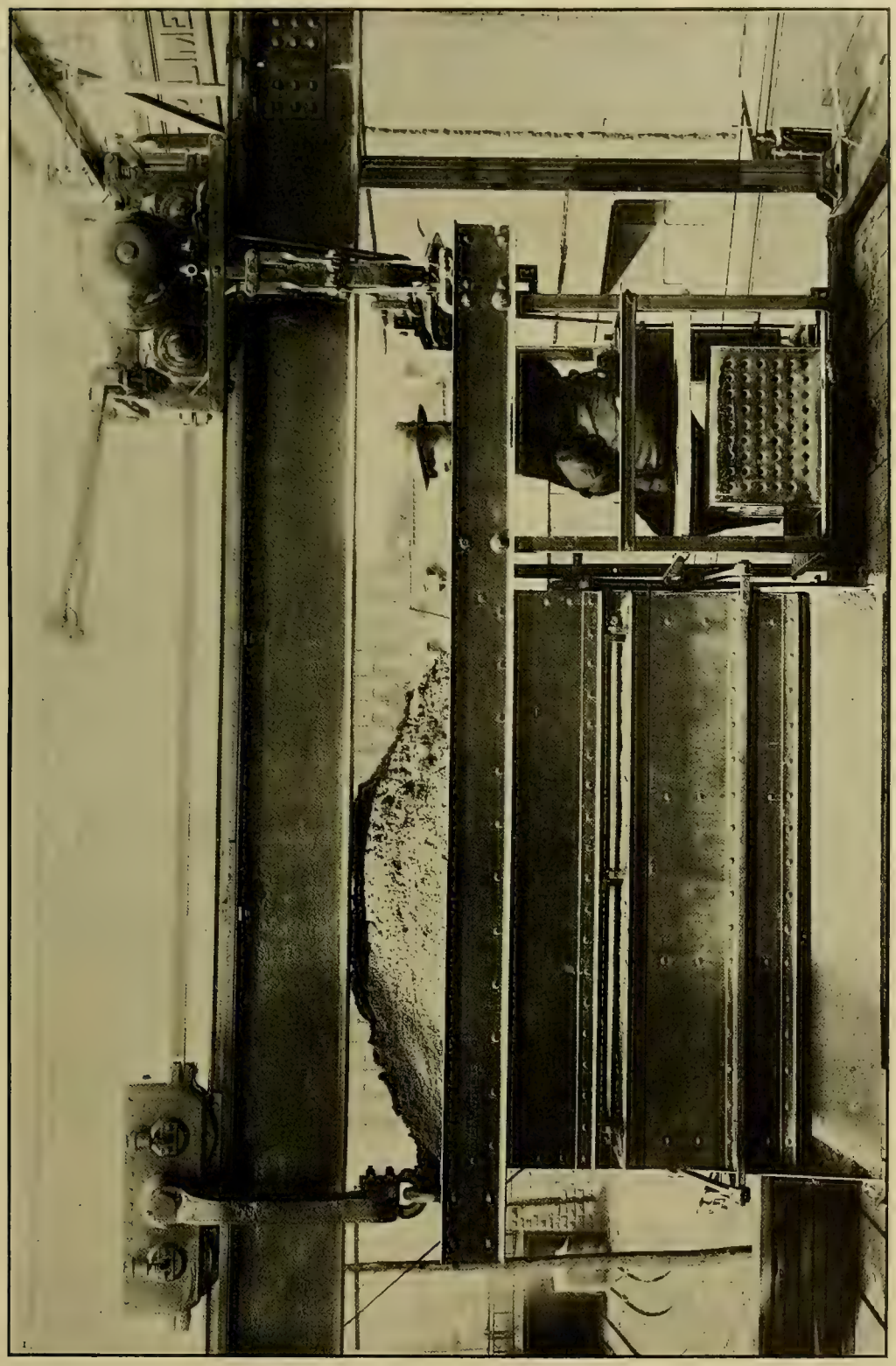
Storage Battery Truck.
Combination of Overhead and Surface Power Trucks, often Provides both for Inside and Outside Service.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



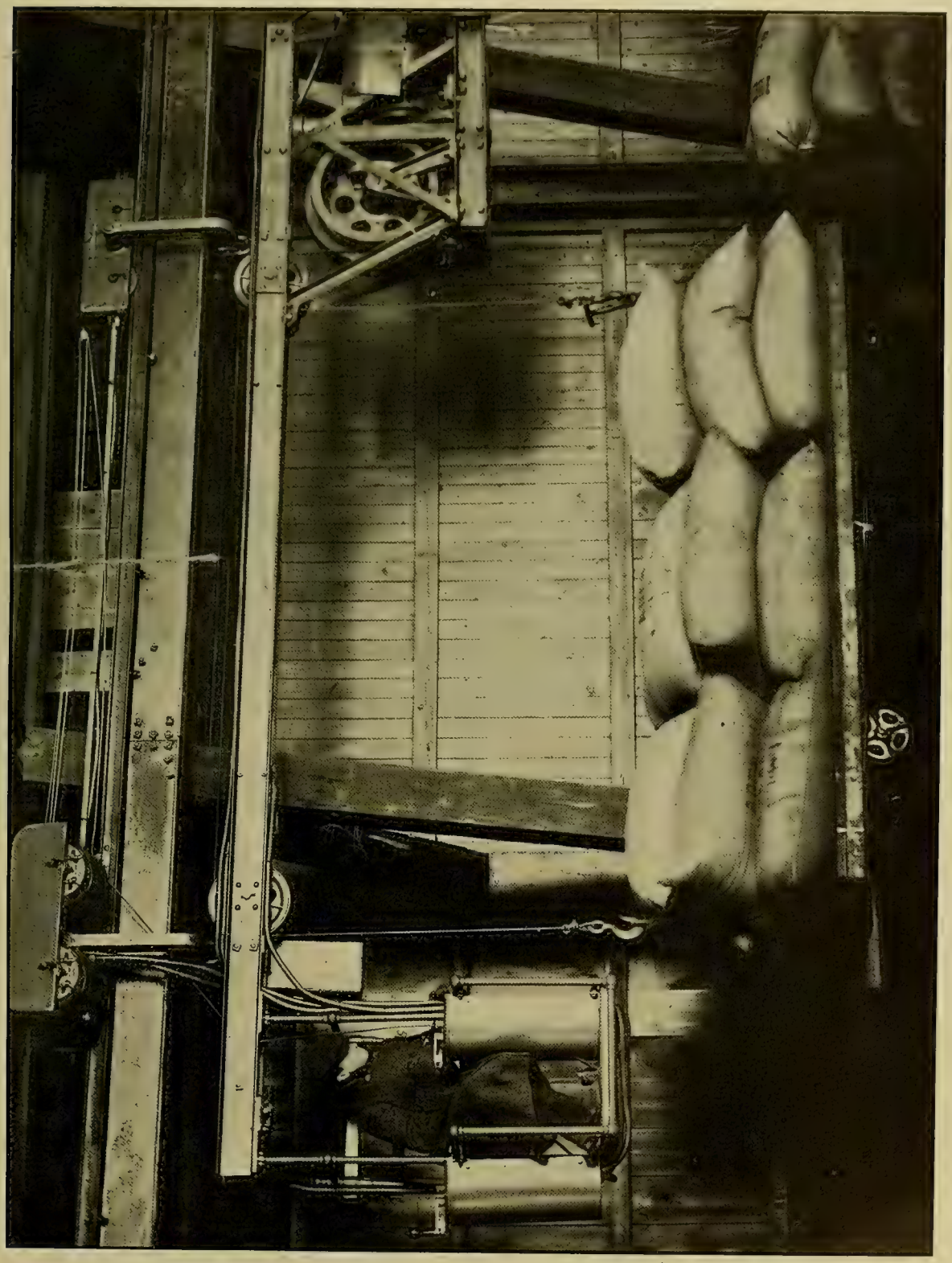
FROM TERMINAL TO WAREHOUSE.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



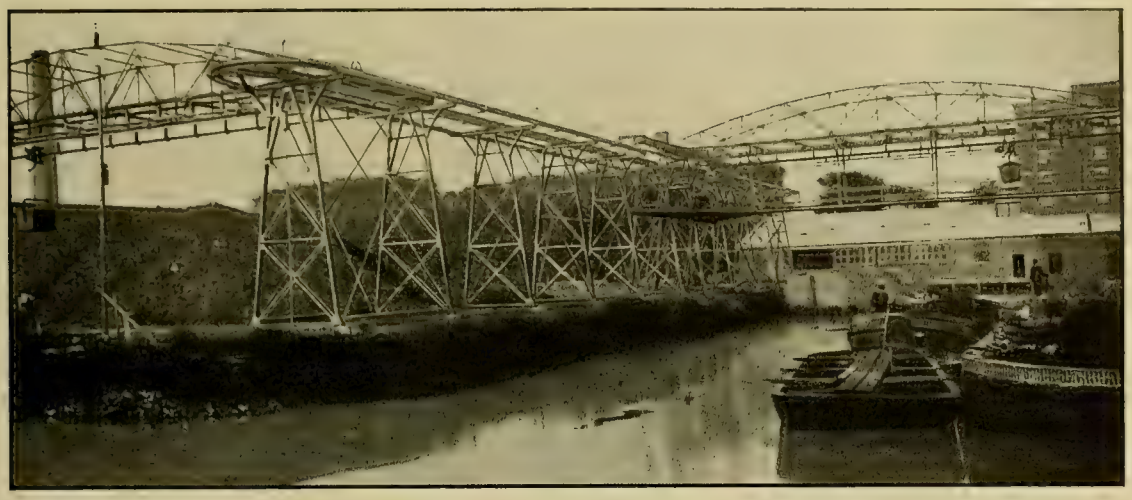
DETAILS OF CONVEYING MACHINERY.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



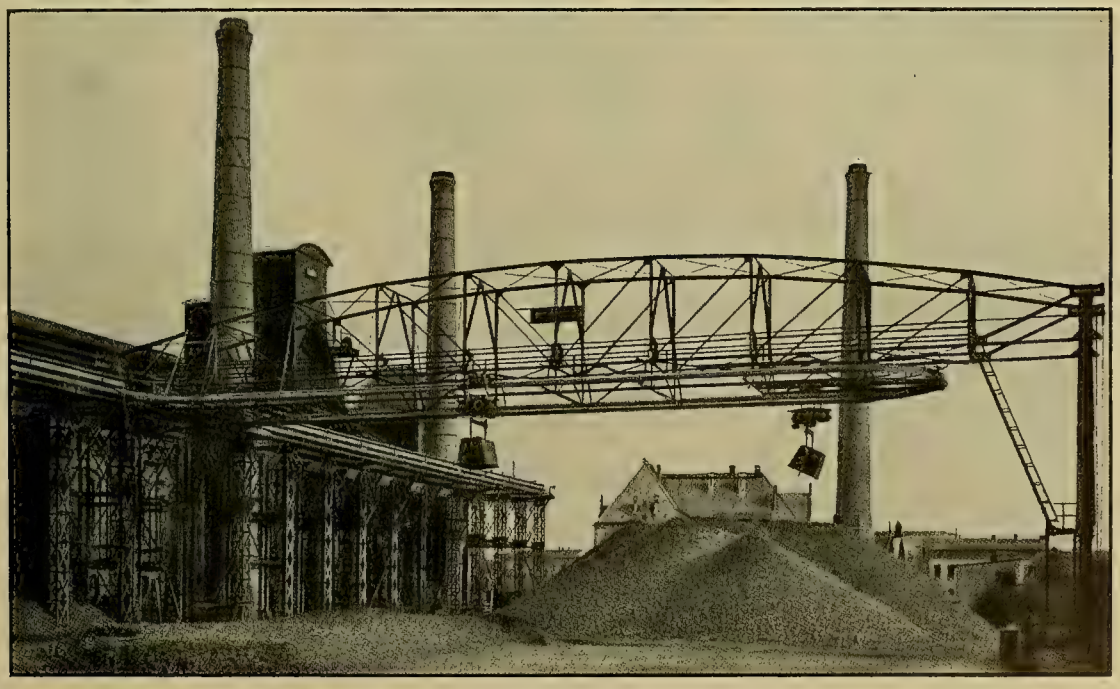
Overhead Track and Telpher in Pier Shed.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



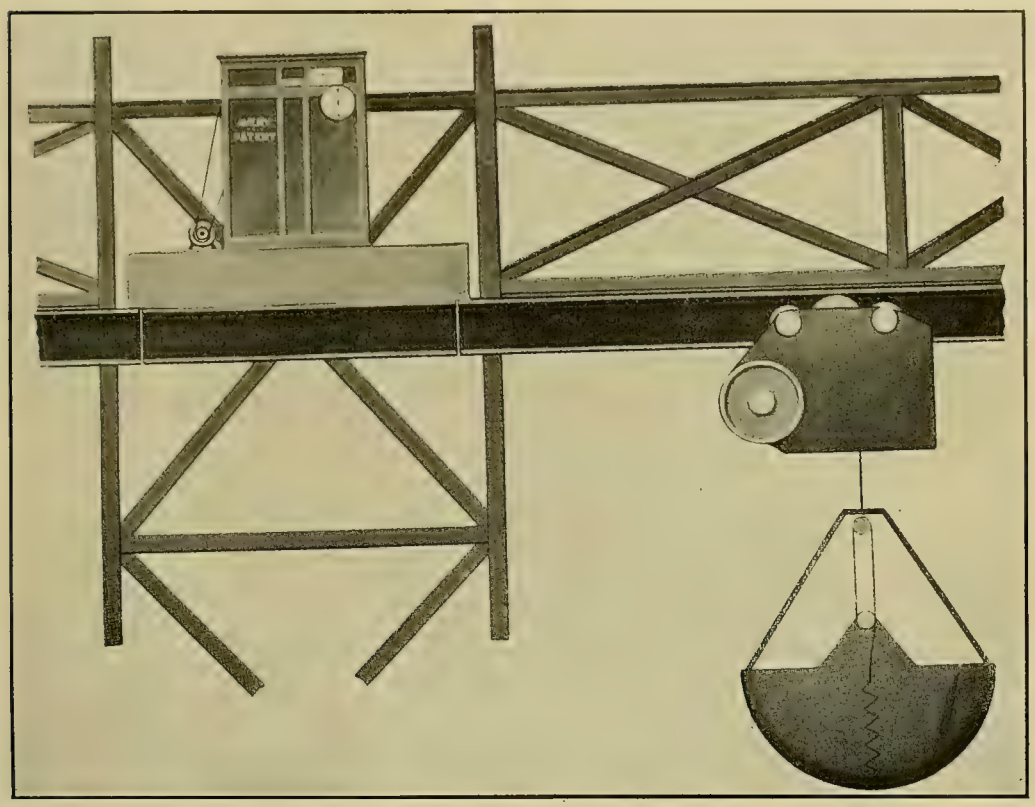
Traveling Bridge Cranes Supporting Movable Tracks with Gliding Contacts, Bromberg, Germany.

Traveling Shop Cranes with Movable Tracks Attached to the Cranes, Serving All Space, Brussels, Belgium.

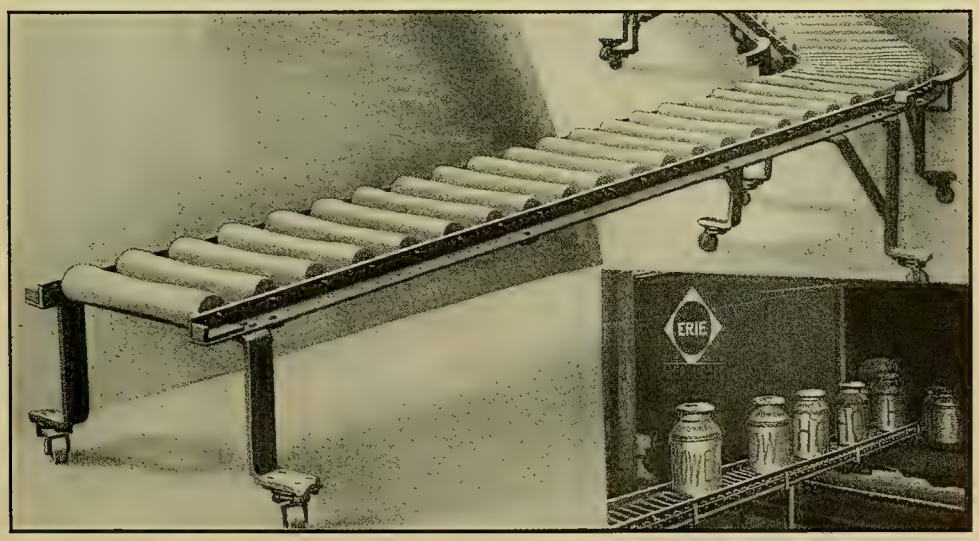


Traveling Gantry Crane, Half Arch, with Moavable Tracks, Groningen, Holland.
The three plants, illustrated above, serve all space, with no rehandling and with continuous rapidity.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.

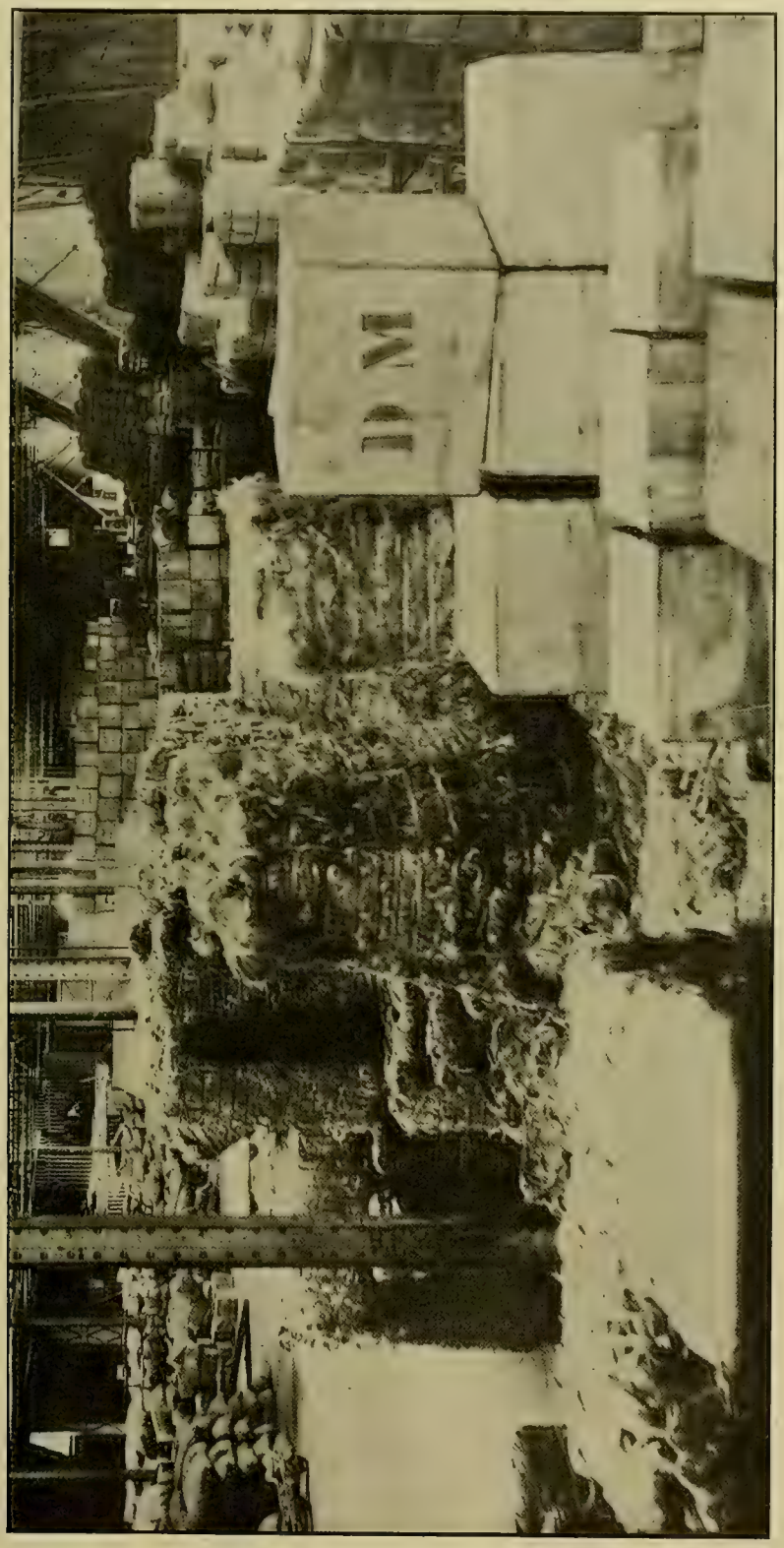


Method of Weighing Automatically in Transit, Giving Weight of Each Net Load and Total Weights.



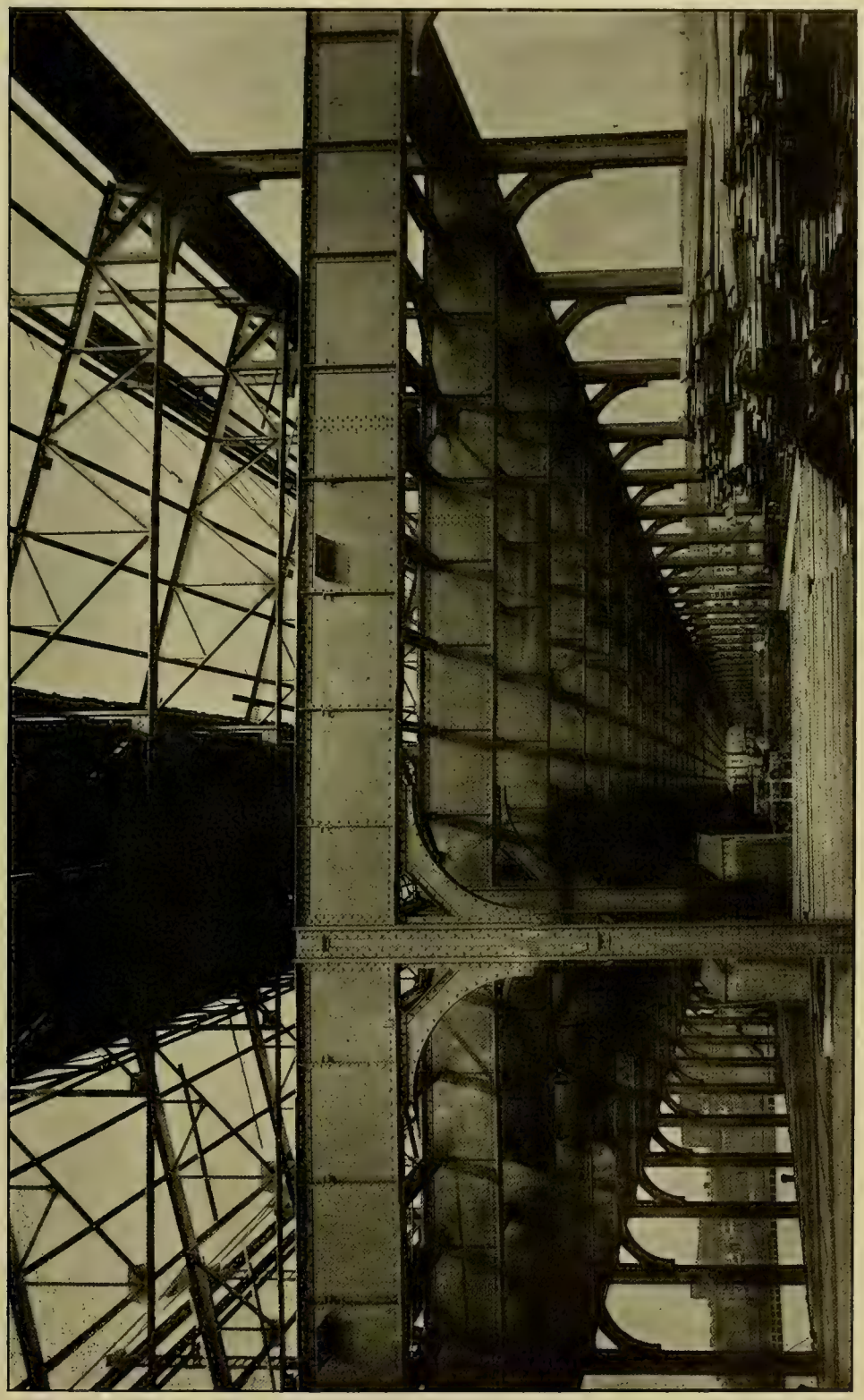
Rollers by which Lowered Loads will pass Automatically Within the Cars.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



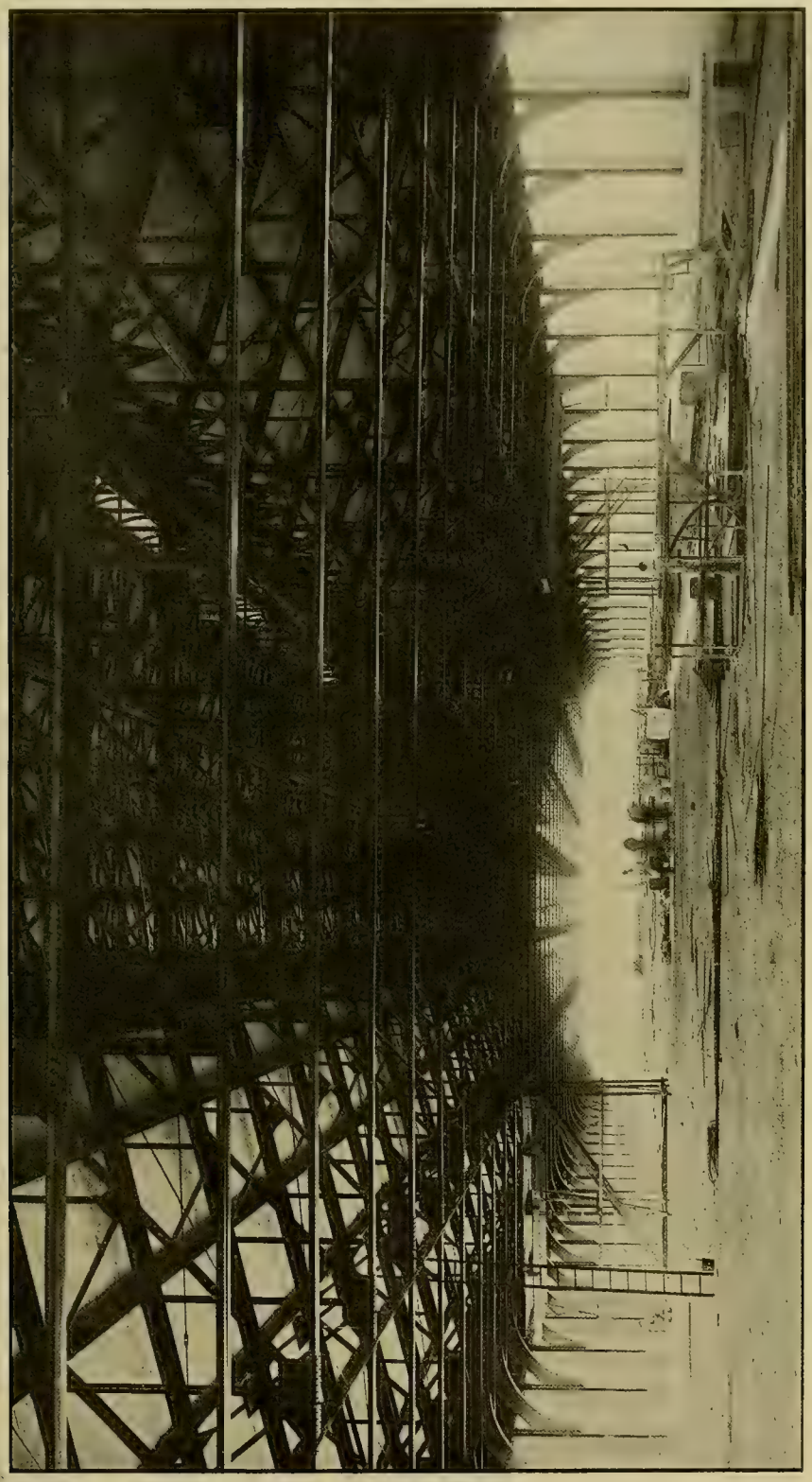
Typical Pier Scene. Little Available Floor Space.

To illustrate paper on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



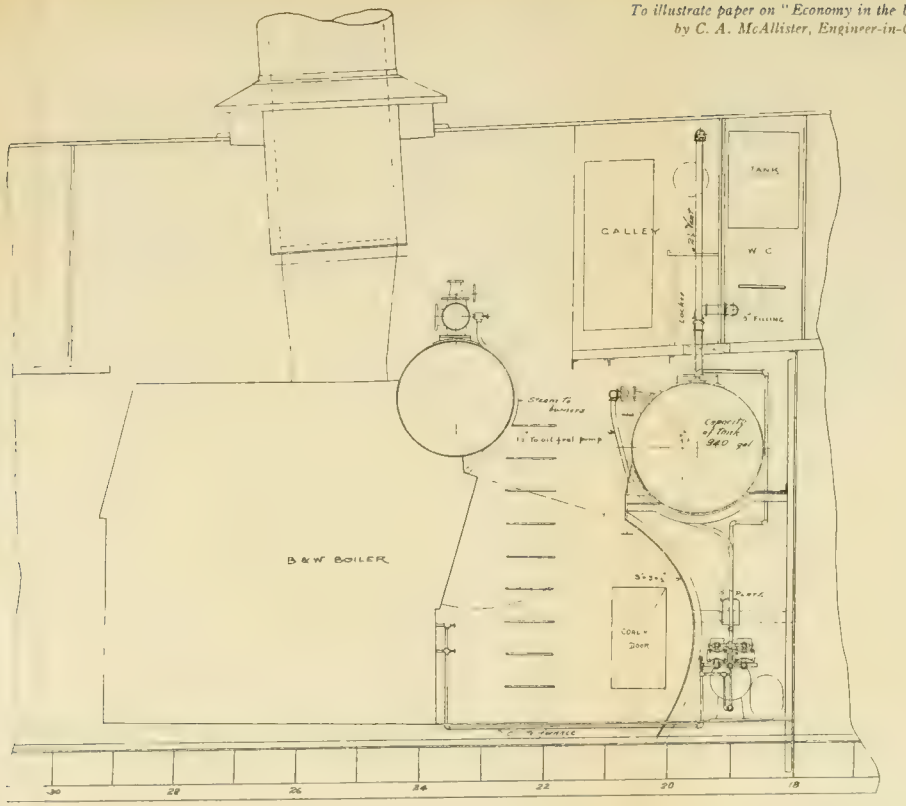
Chelsea Pier Construction, North River, N. Y.

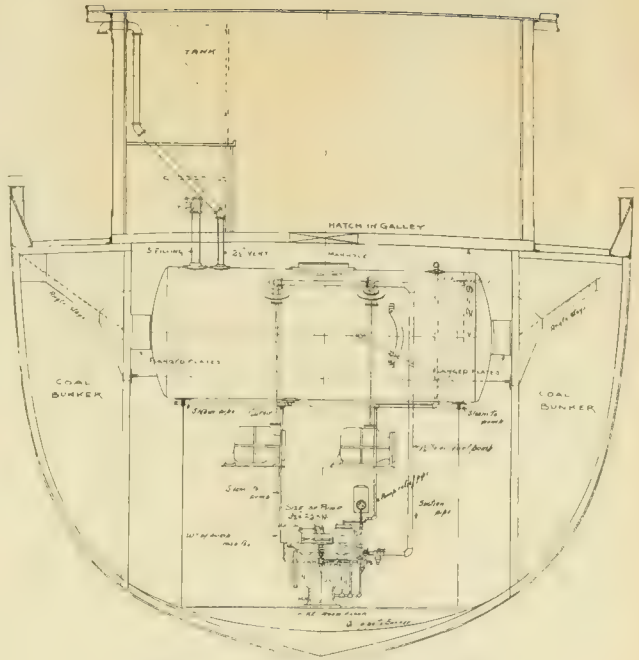
To illustrated page on "Cargo Transference at Steamship Terminals," by H. McL. Harding, Esq., Consulting Engineer.



Chelsea Pier Construction, North River, N. Y.

To illustrate paper on "Economy in the Use of Oil as Fuel for Harbor Vessels," by C. A. McAllister, Engineer-in-Chief, U. S. R. C. S., Member

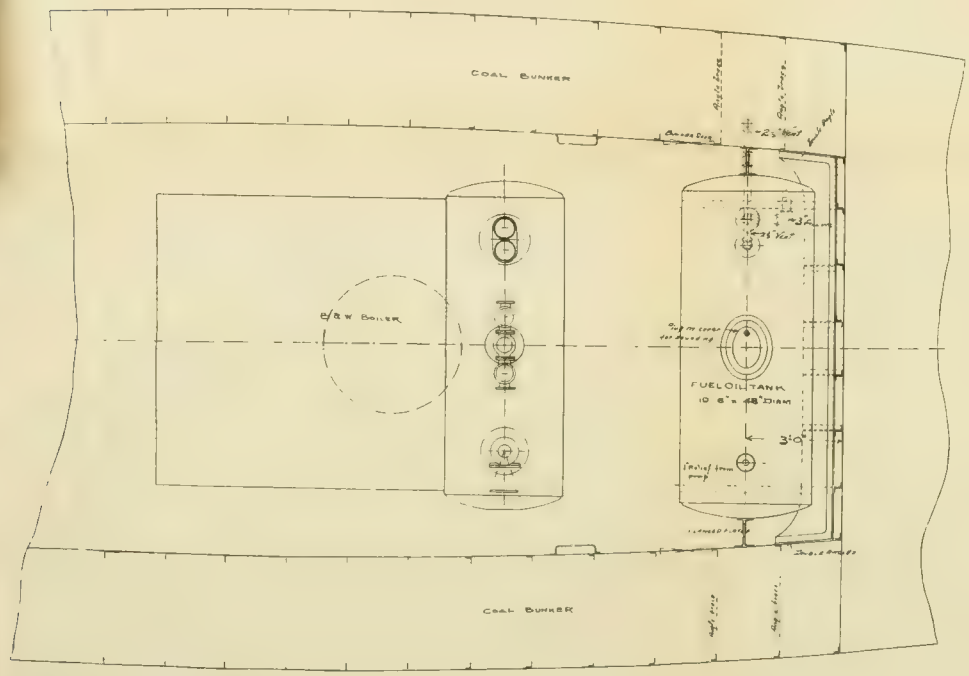


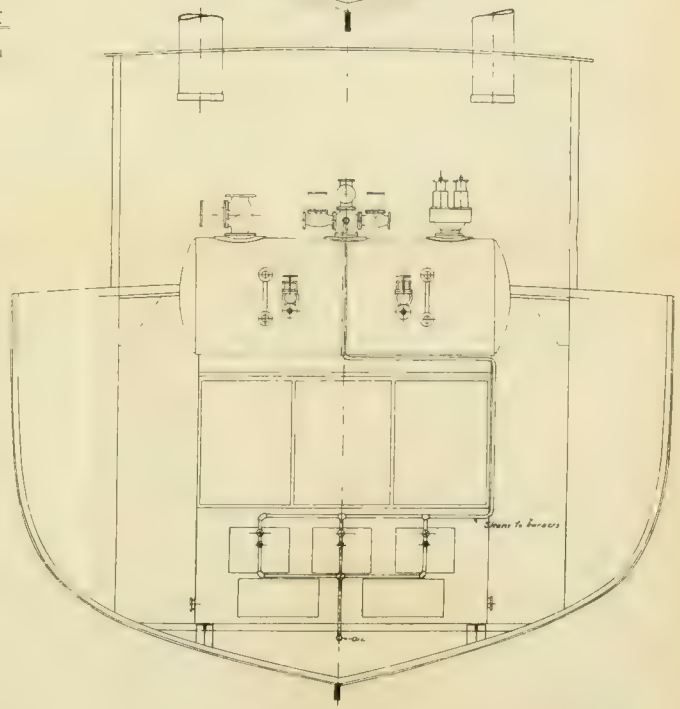


U.S. REVENUE CUTTER

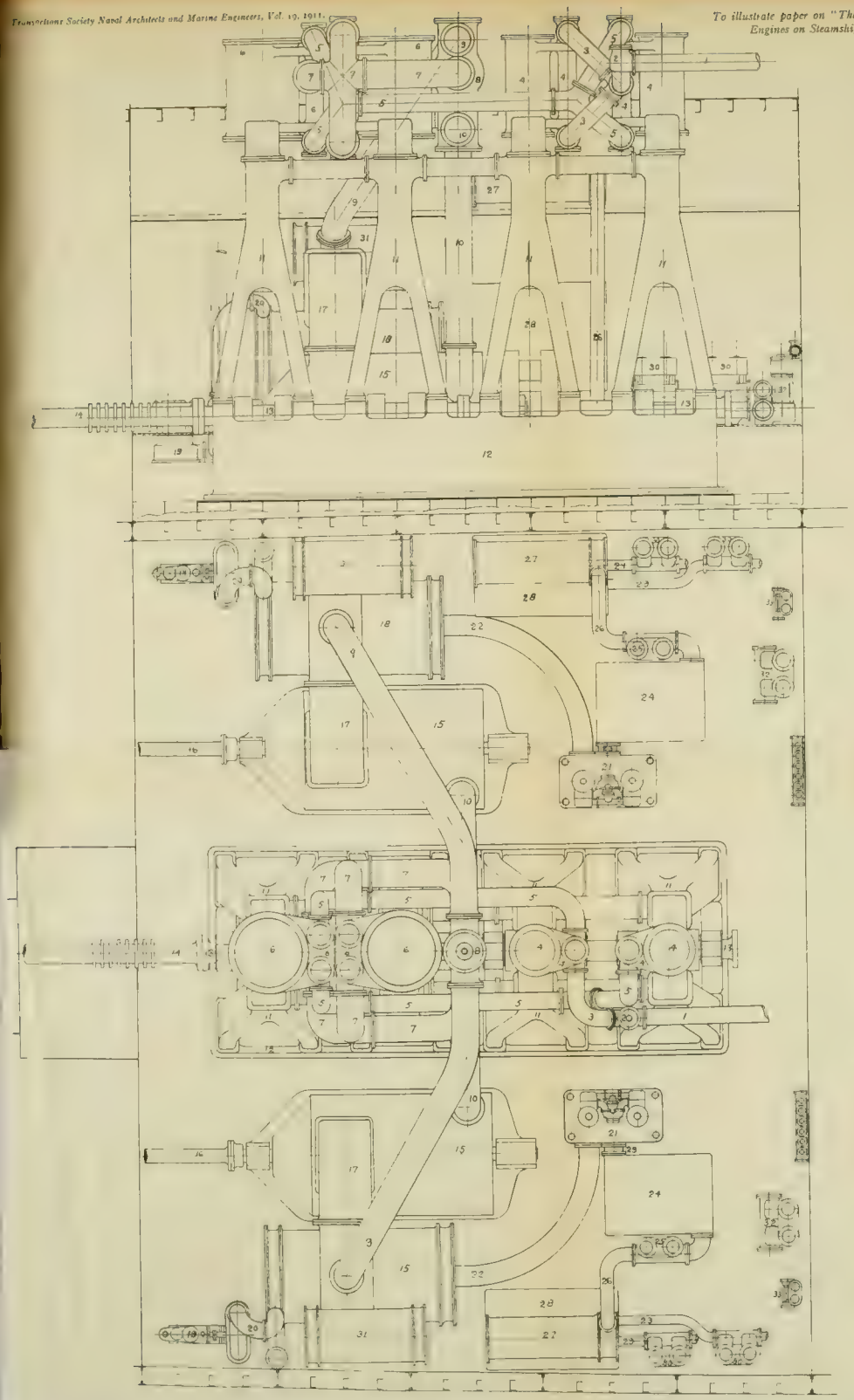
GOLDEN GATE

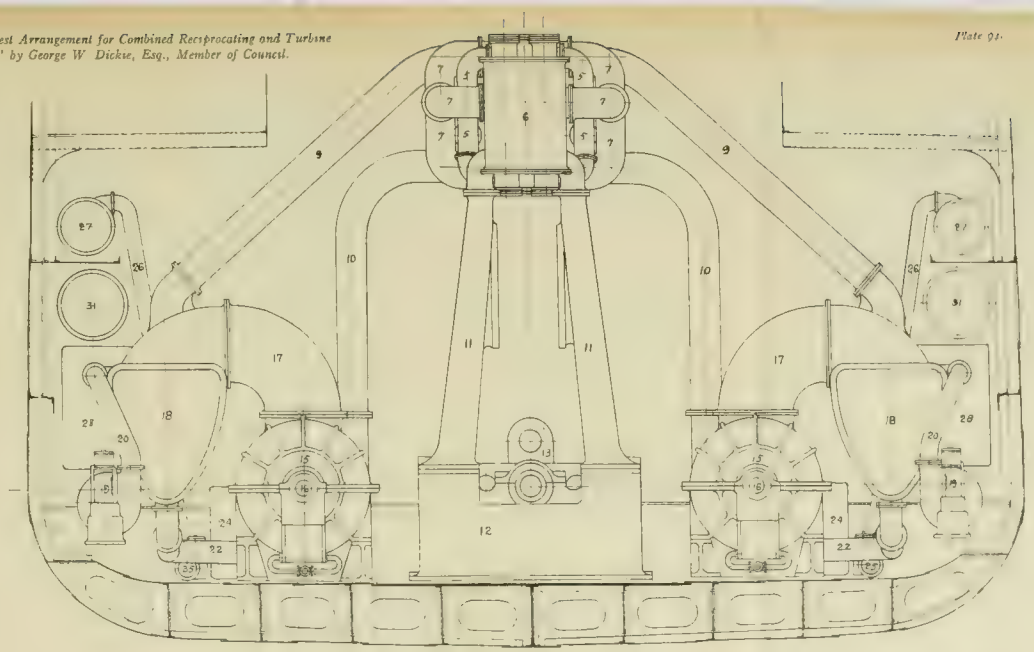
OIL FUEL INSTALLATION





To illustrate paper on "The Best Arrangement for Combined Reciprocating and Turbine Engines on Steamships," by George W. Dickie, Esq., Member of Council.

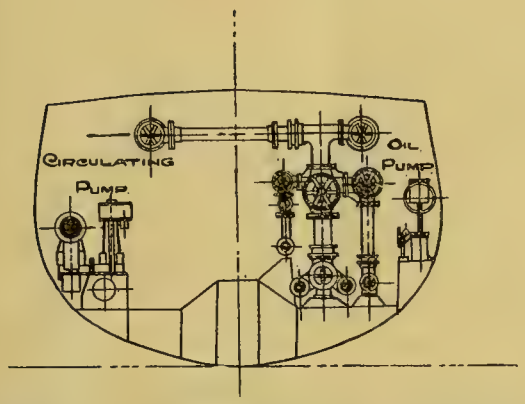




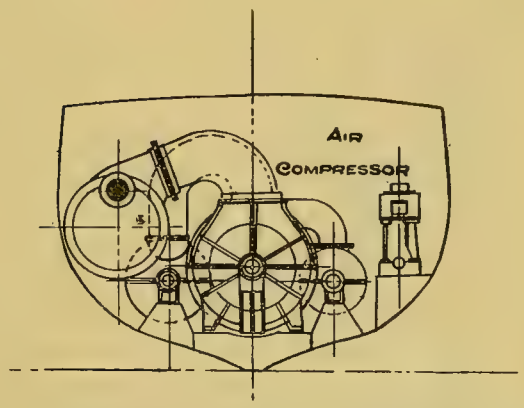
1 Main Steam Pipe From Boilers
2 Main Throttle Valve For H.P. Cylinders
3 Steam Pipe Connection To After H.P. Cylinder
4 H.P. Steam Chests And Cylinders
5 Steam Pipe Connections From H.P. Steam Chests To L.P. Steam Chests
6 L.P. Steam Chests And Cylinders
7 Exhaust Pipes From L.P. Steam Chests To Change Valve
8 Change Valve
9 Exhaust Pipes From Change Valve To Condensers
10 Exhaust Pipes From Change Valve To L.P. Turbines
11 Reciprocating Engine Frames
12 Reciprocating Engine Bed Plate
13 Crank Shaft
14 Thrust Shaft
15 Low Pressure Turbines
16 Low Pressure Turbine Shafts
17 Main Exhausts From Turbines To Condensers
18 Main Condensers
19 Main Circulating Pumps
20 Circulating Water Pipes
21 Main Air Pumps
22 Suction Pipes From Condensers To Air Pumps
23 Discharge From Air Pumps To Hot Well And Filter Tanks
24 Hot Well And Filter Tanks
25 Hot Well Pumps
26 Discharge Pipes From Hot Well Pumps To Surface Heaters
27 Surface Heaters
28 Main Feed Tanks
29 Suction Pipes From Main Feed Tanks To Main Feed Pumps
30 Main Feed Pumps
31 Auxiliary Condensers – Pumps Underneath
32 Bilge Pumps
33 Sanitary Pumps

PROPOSED ARRANGEMENT OF MARINE COMPOUND RECIPROCATING AND LOW PRESSURE TURBINE ENGINES

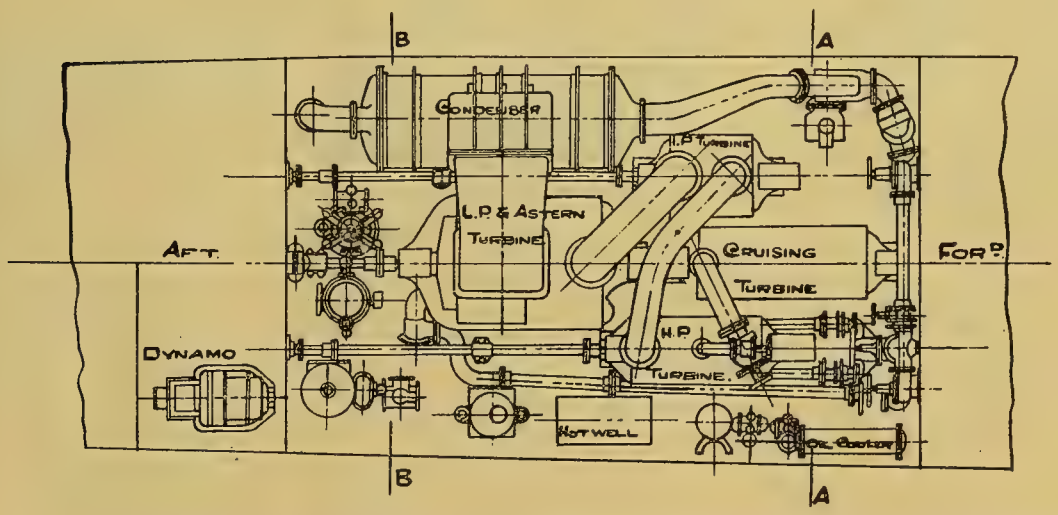
To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



Section at "A.A." Looking For^d.

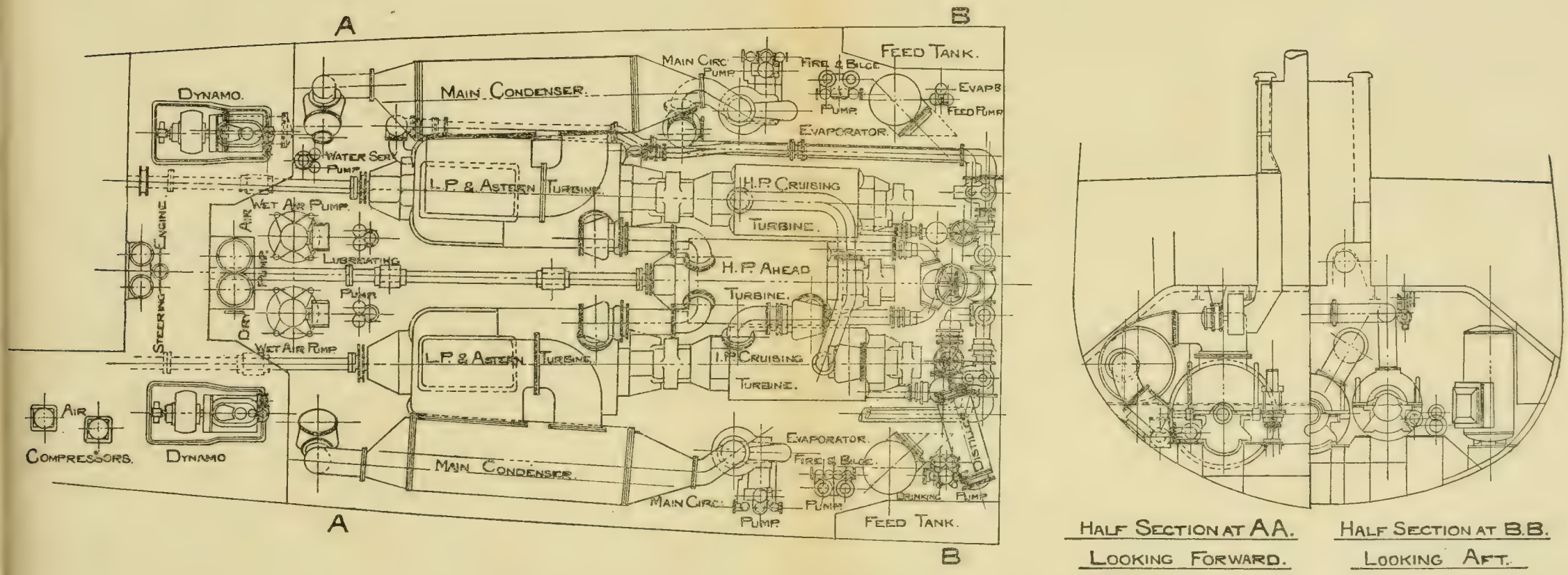


Section at "B.B." Looking For^d.



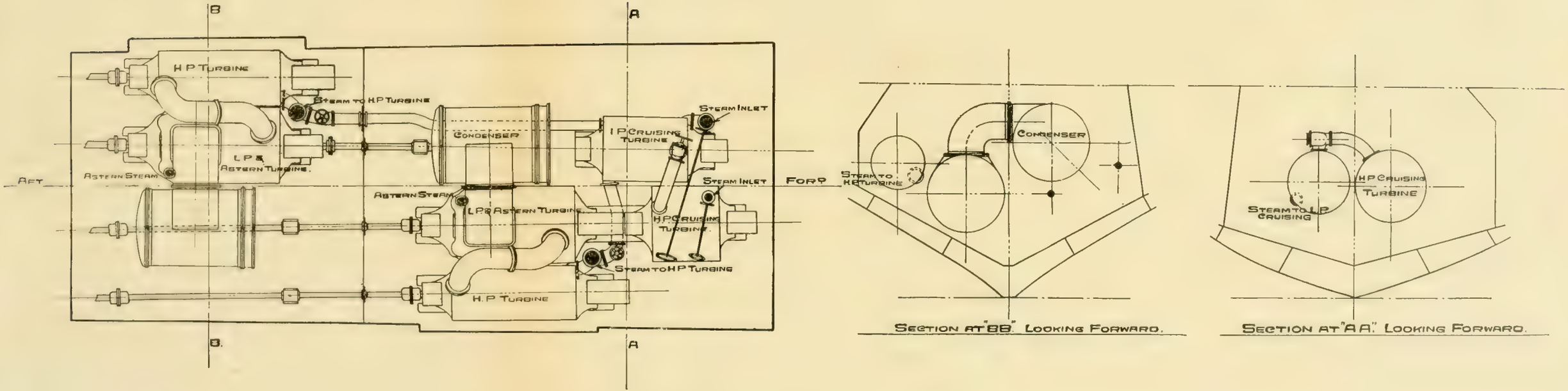
General Arrangement of Turbine Machinery for First Class Torpedo Boats and Small Fast Steam Yachts.

To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



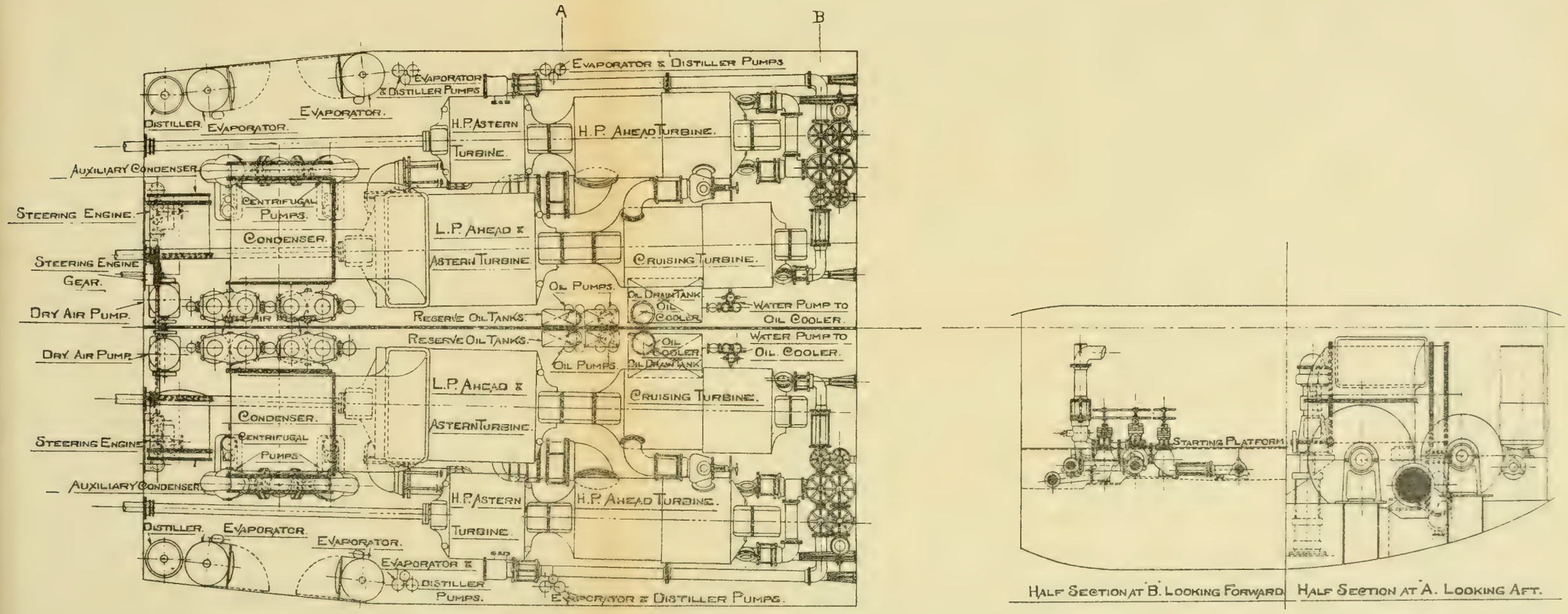
General Arrangement of Turbine Machinery with Three Shafts Suitable for Destroyers and Scouts.

To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



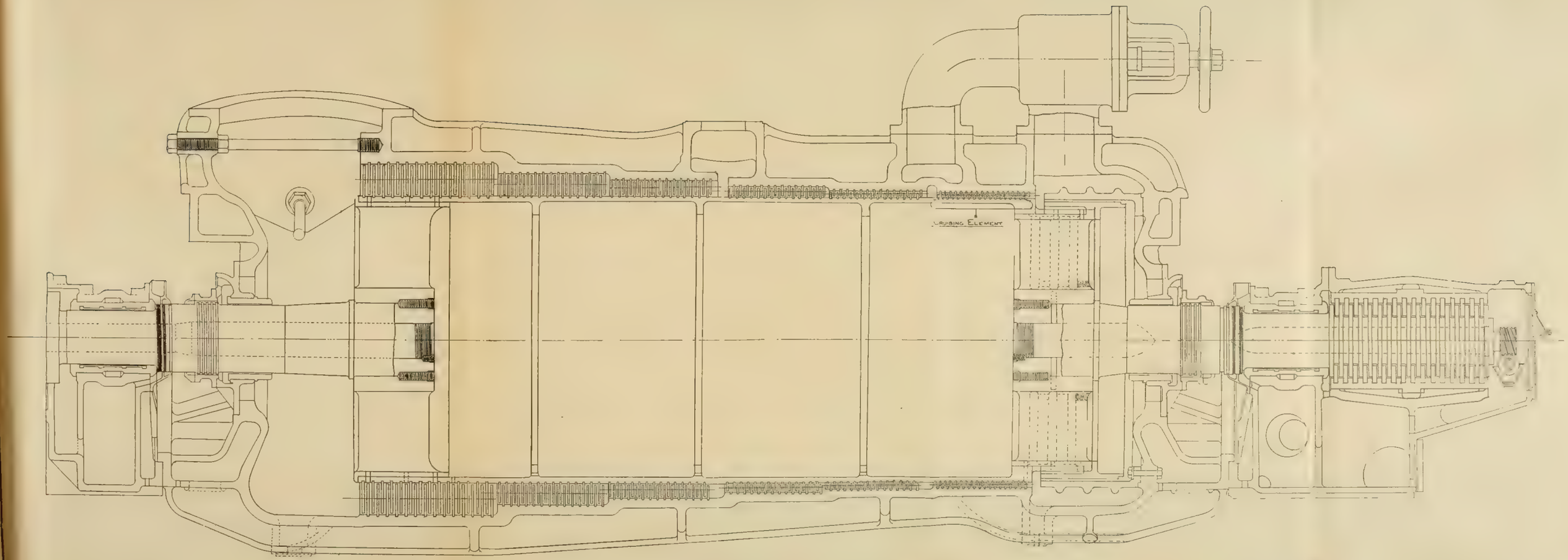
General Arrangement of Turbines in United States Scout Cruiser Chester.

To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



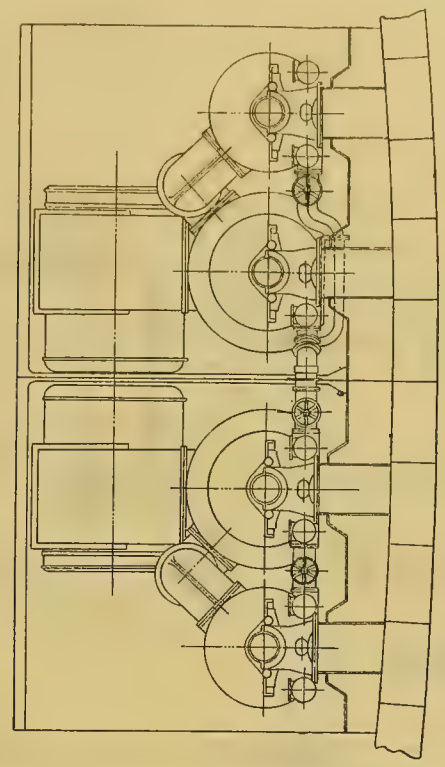
General Arrangement of Turbine Machinery for a Battleship with Cruising Turbines in Parallel.

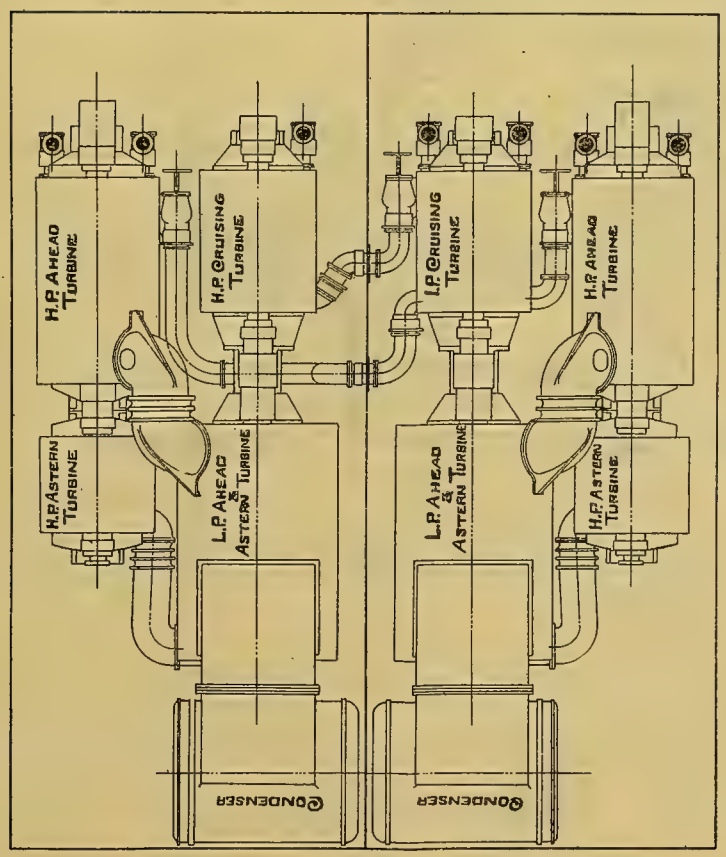
To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



SECTIONAL VIEW OF HIGH PRESSURE AHEAD TURBINE WITH CRUISING ELEMENT.

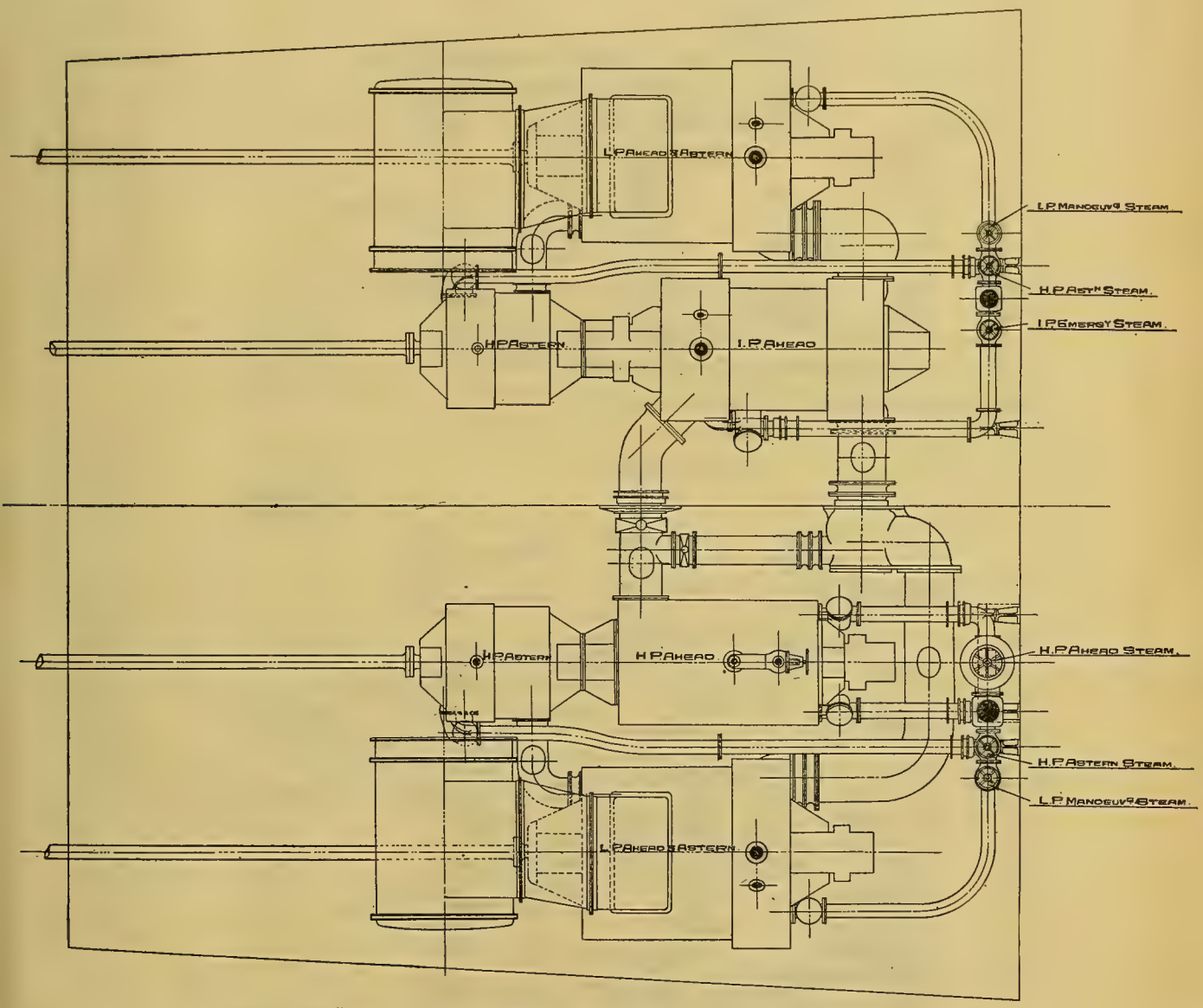
To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.





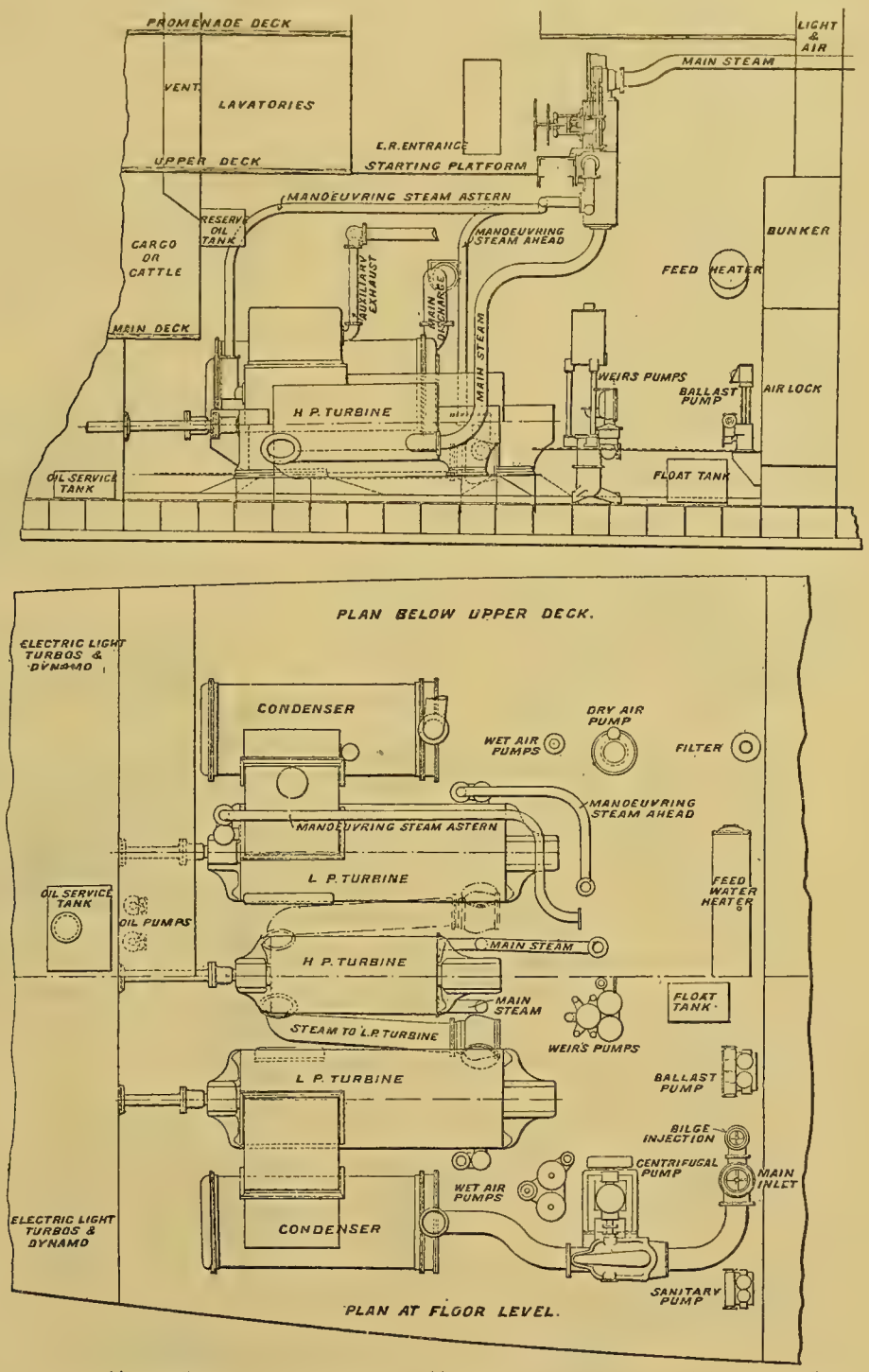
4 Shaft General Arrangement of Turbine Machinery with Cruising Turbines in Series.
U. S. S. Utah, Florida, Wyoming and Arkansas.

To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



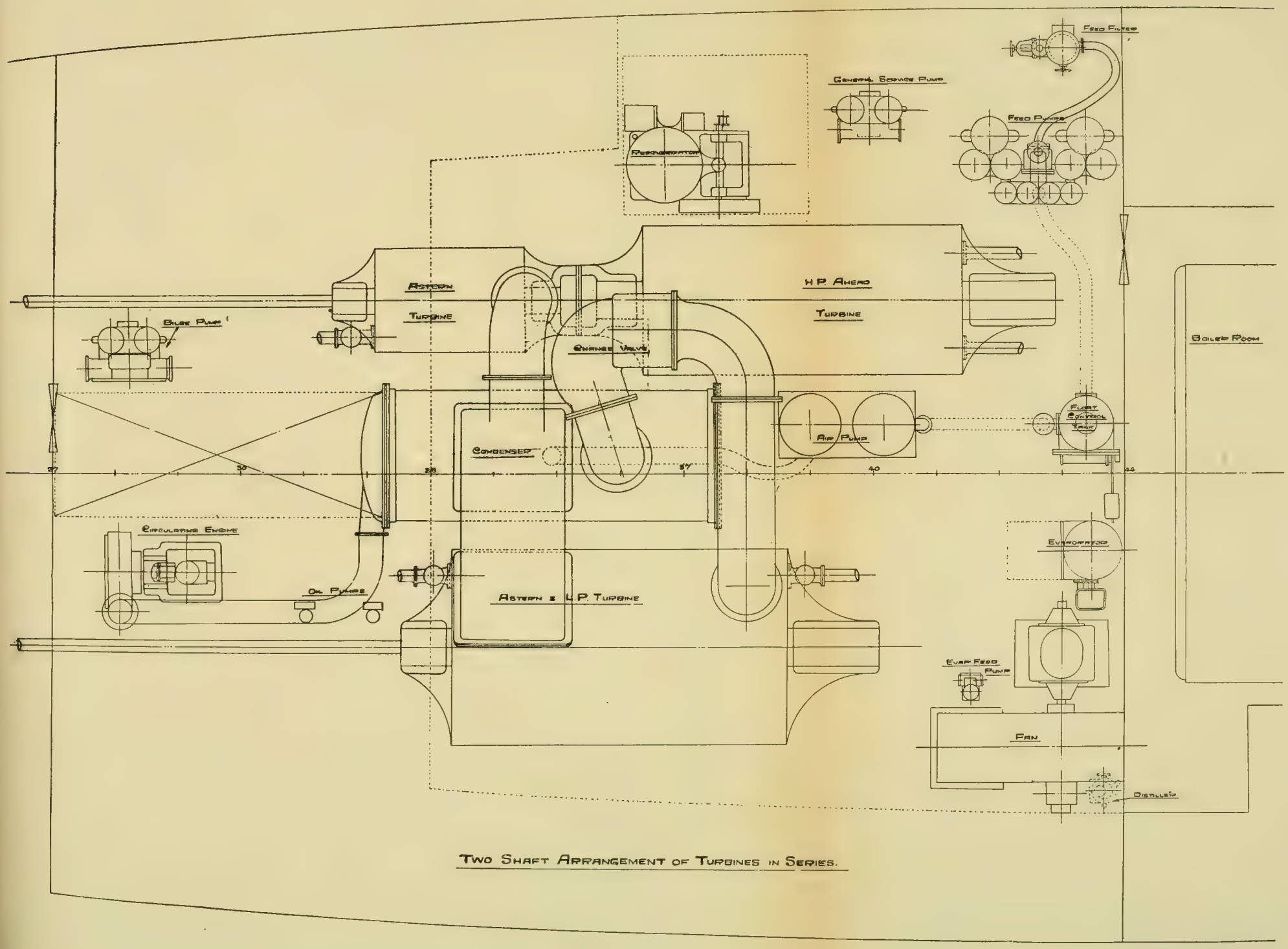
General Arrangement of Turbine Machinery in Series.

To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



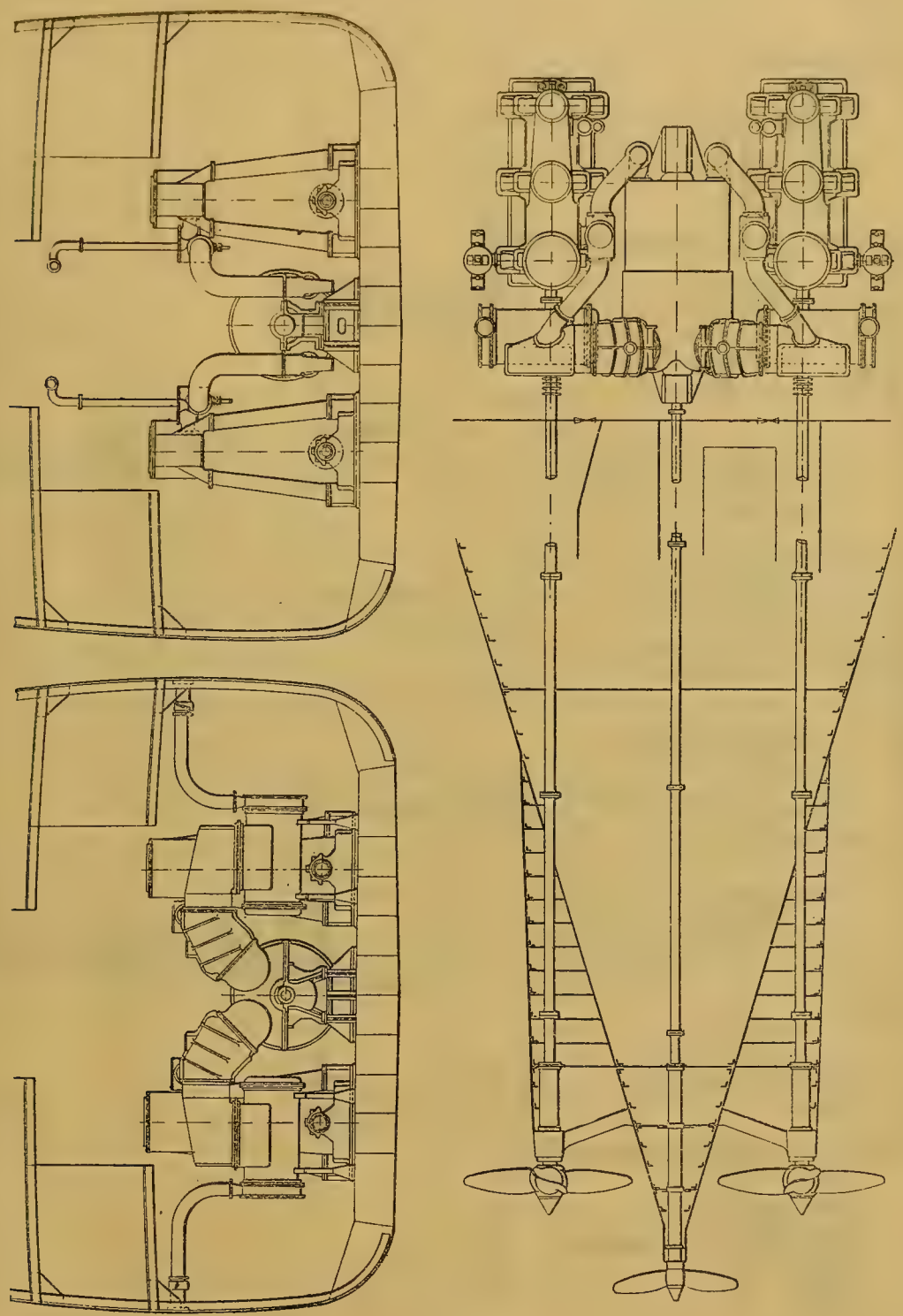
STANDARD THREE-SHAFT ARRANGEMENT OF TURBINE MACHINERY FOR MERCHANT SHIPS.

To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



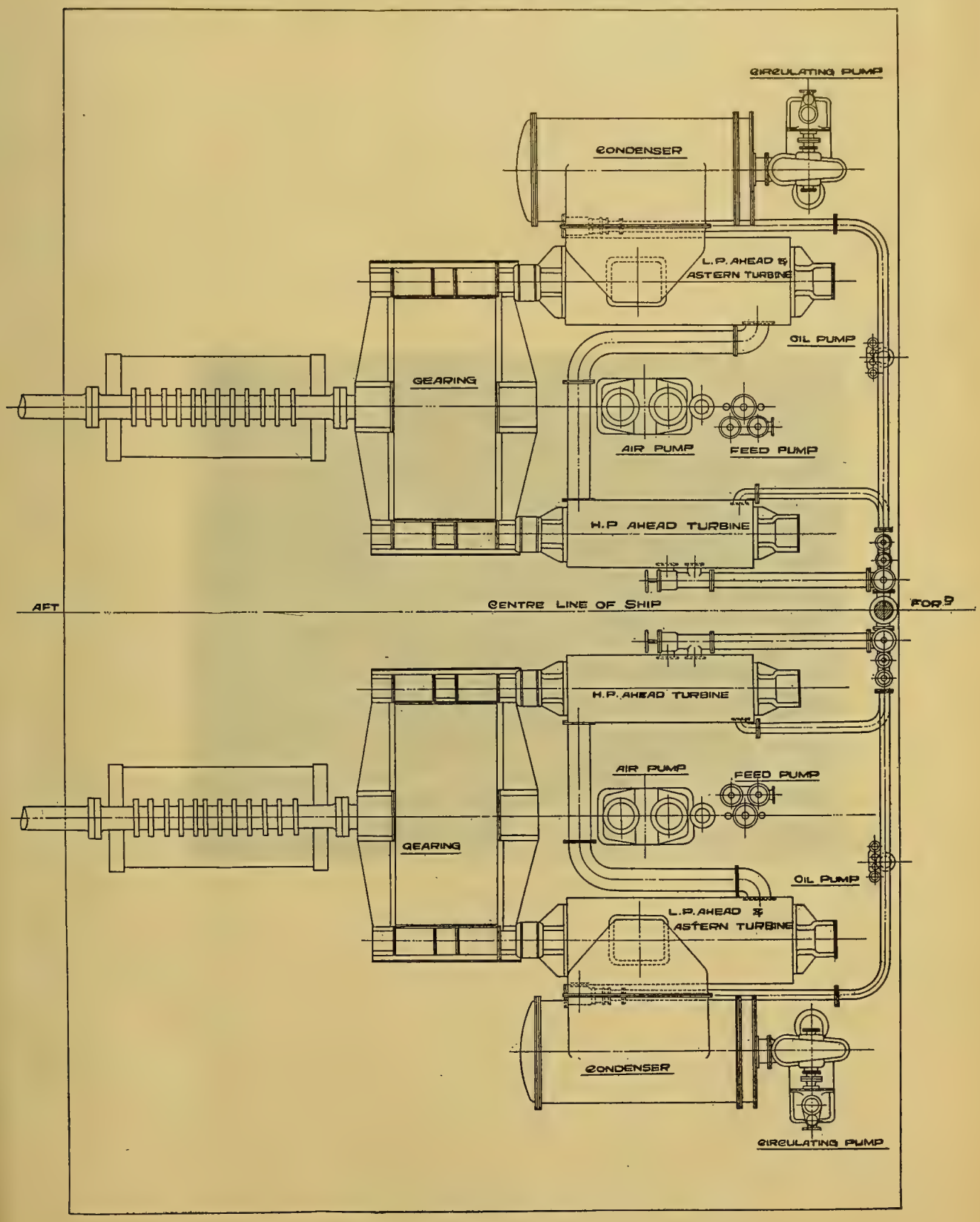
Two Shaft Arrangement of Turbines in Series.

To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



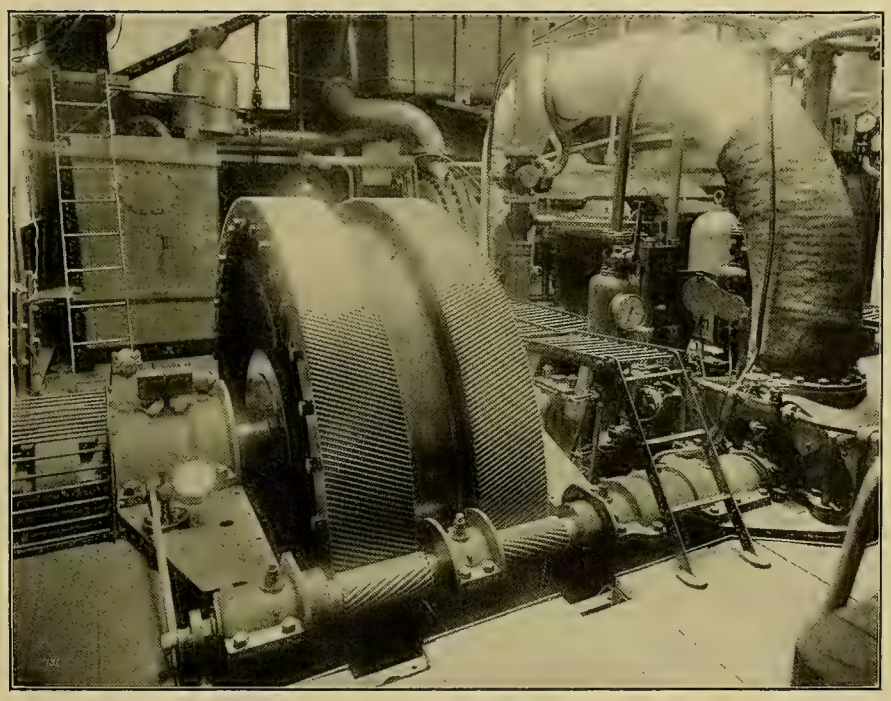
General Arrangement of Machinery. S. S. Otaki.

To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



General Arrangement of Geared Turbines with Twin Screws.

To illustrate paper on "The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels," by E. H. B. Anderson, Esq., Member.



VESPASIAN GEAR WHEEL.

To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Frank E. Kirby, Esq., and William T. Donnelly, Esq., Members.

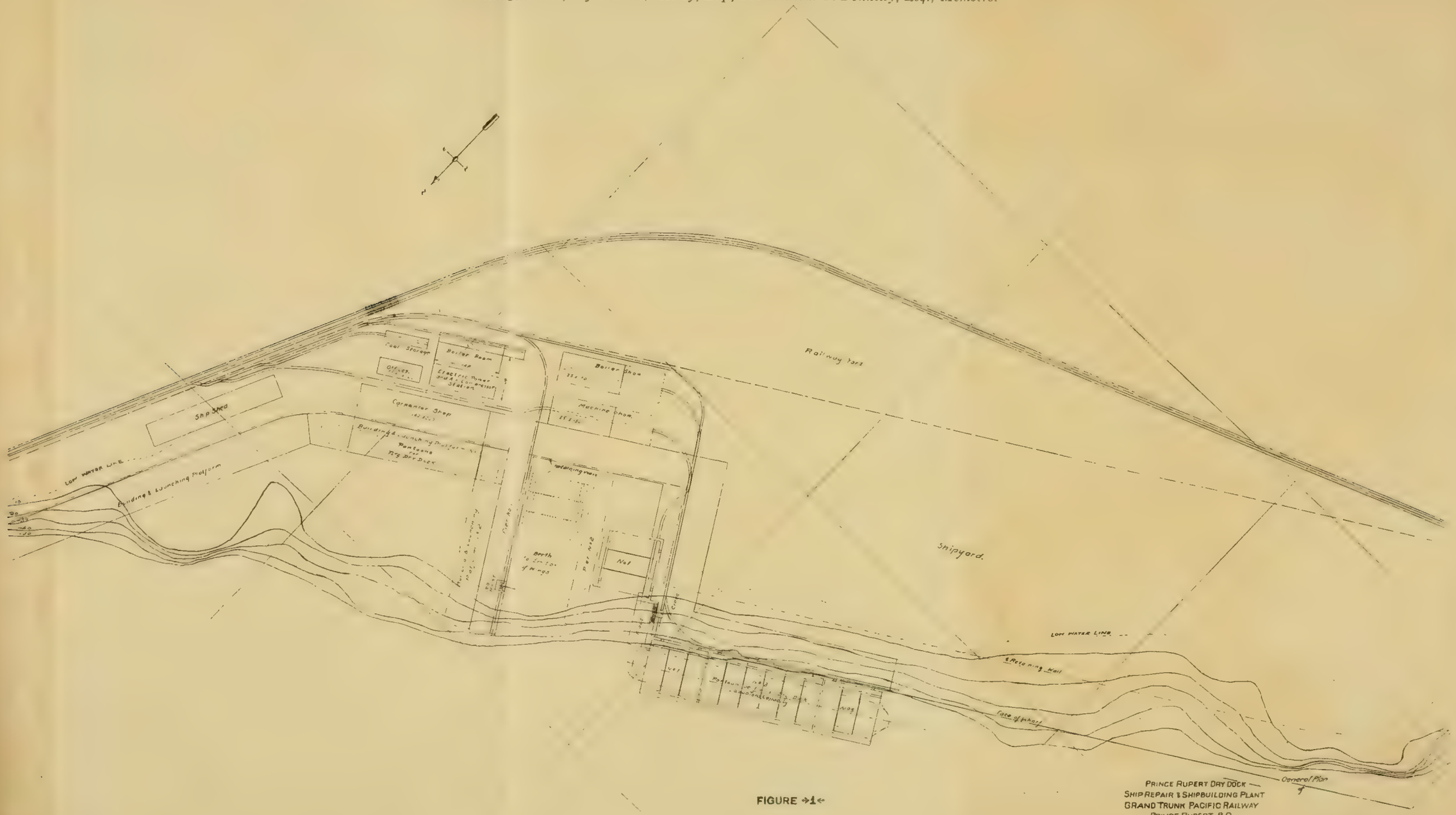


FIGURE →1←

To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Frank E. Kirby, Esq., and William T. Donnelly, Esq., Members.

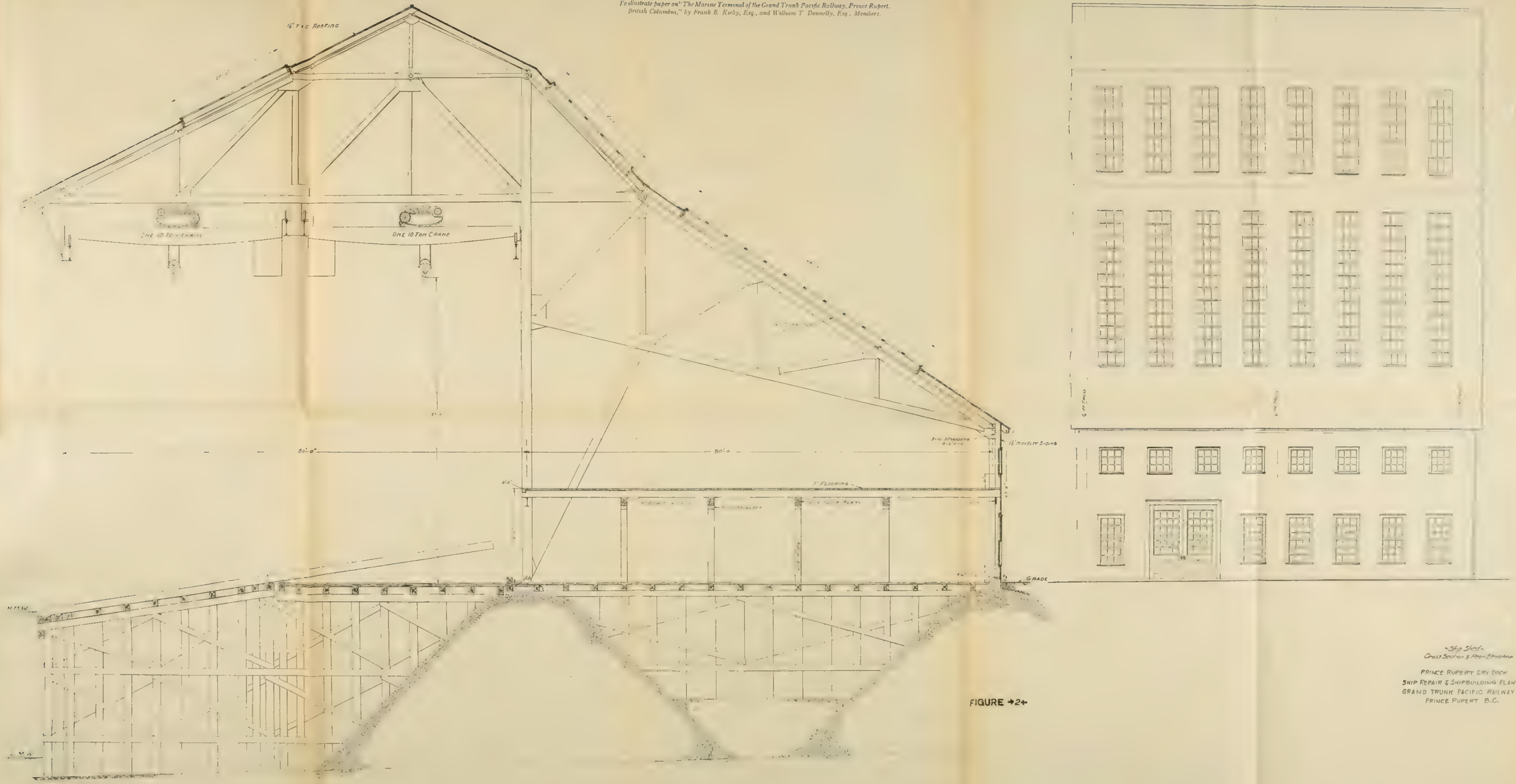
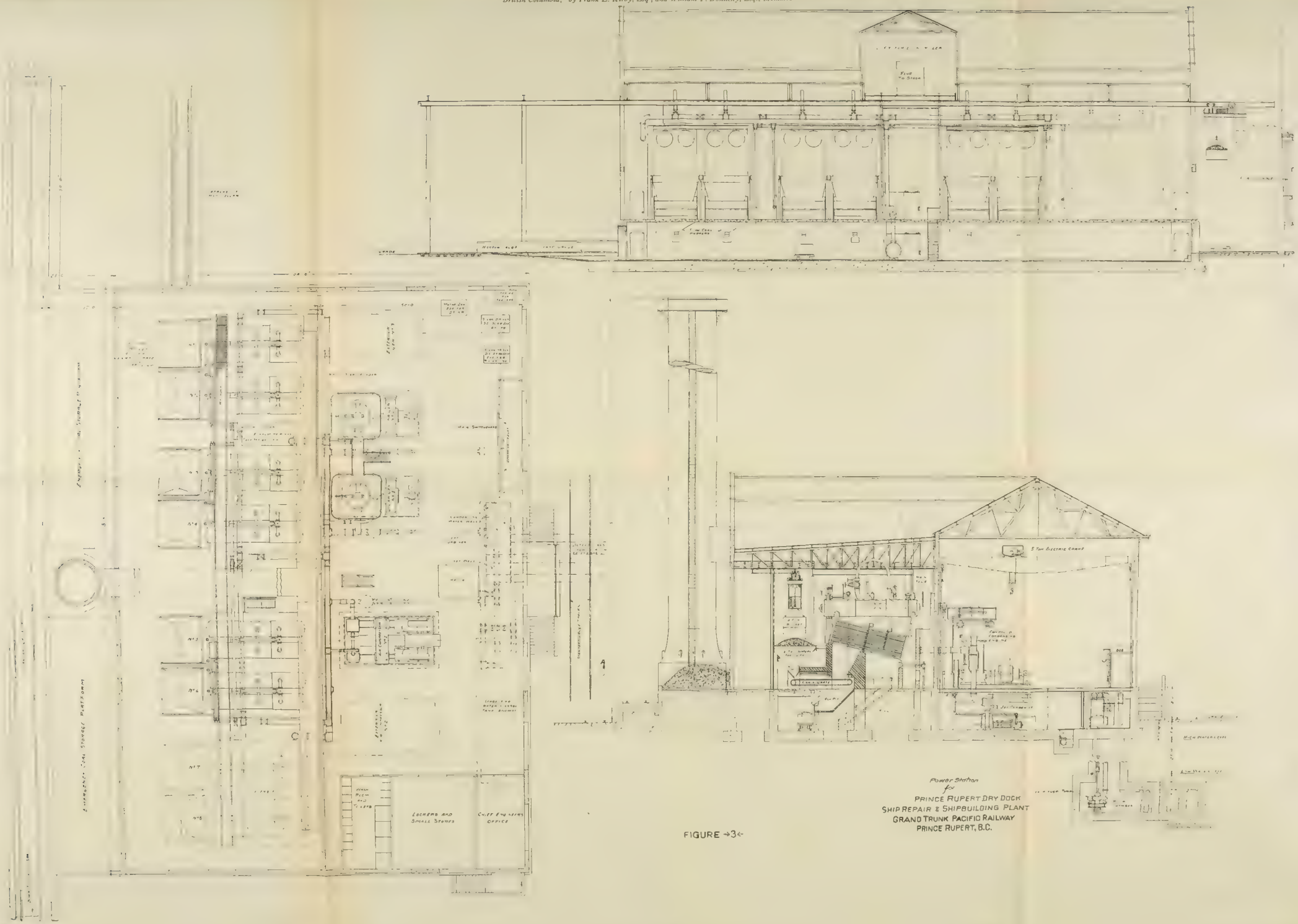


FIGURE →2←

"Ship Shed"
Cross Section & Plan Elevation

PRINCE RUPERT DRY DOCK
SHIP REPAIR & SHIPBUILDING PLANT
GRAND TRUNK PACIFIC RAILWAY
PRINCE RUPERT B.C.

To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Frank E. Kirby, Esq., and William T. Donnelly, Esq., Members



Power Station for PRINCE RUPERT DRY DOCK SHIP REPAIR & SHIPBUILDING PLANT GRAND TRUNK PACIFIC RAILWAY PRINCE RUPERT, B.C.

FIGURE →3←

To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Frank E. Kerby, Esq., and William T. Donnelly, Esq., Members

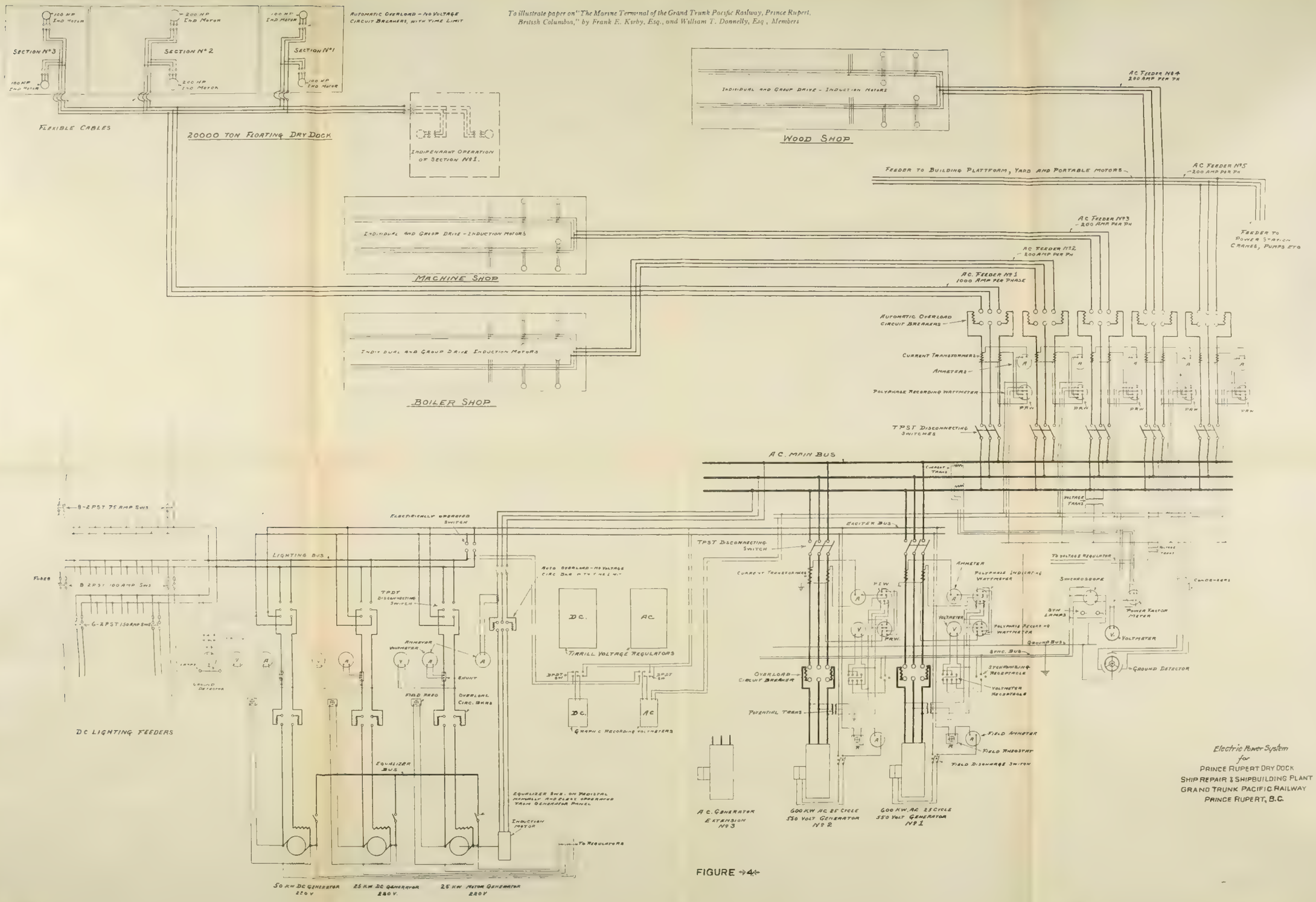


FIGURE 4

Electric Power System for Prince Rupert Dry Dock Ship Repair & Shipbuilding Plant Grand Trunk Pacific Railway Prince Rupert, B.C.

To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Frank E. Kirby, Esq., and William T. Donnelly, Esq., Members.

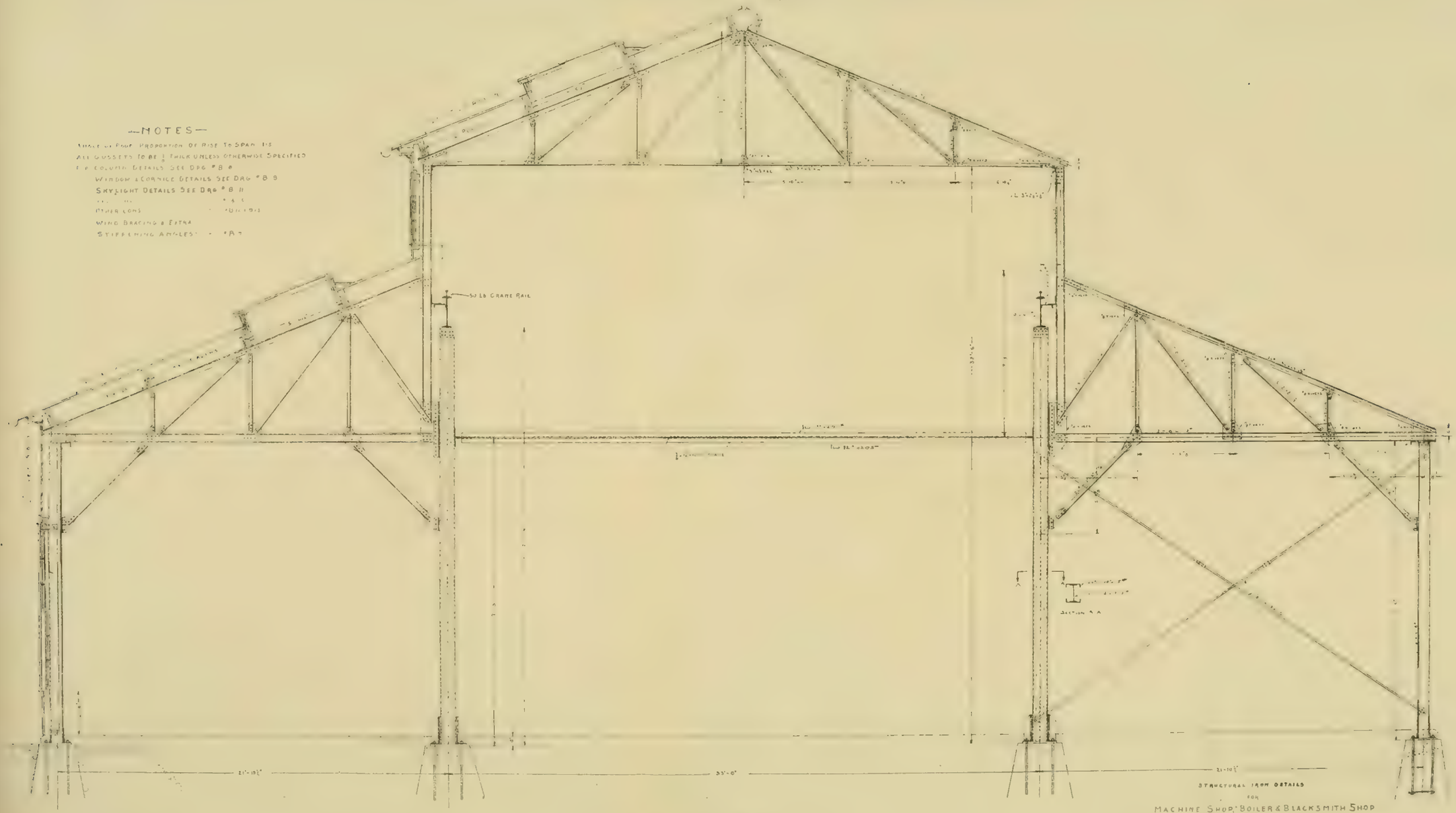


FIGURE 5

STRUCTURAL IRON DETAILS
FOR
MACHINE SHOP, BOILER & BLACKSMITH SHOP
FOR
PRINCE RUPERT DRYDOCK, SHIP REPAIR & SHIP BUILDING PLANT

To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Frank E. Kirby, Esq., and William T. Donnelly, Esq., Members.

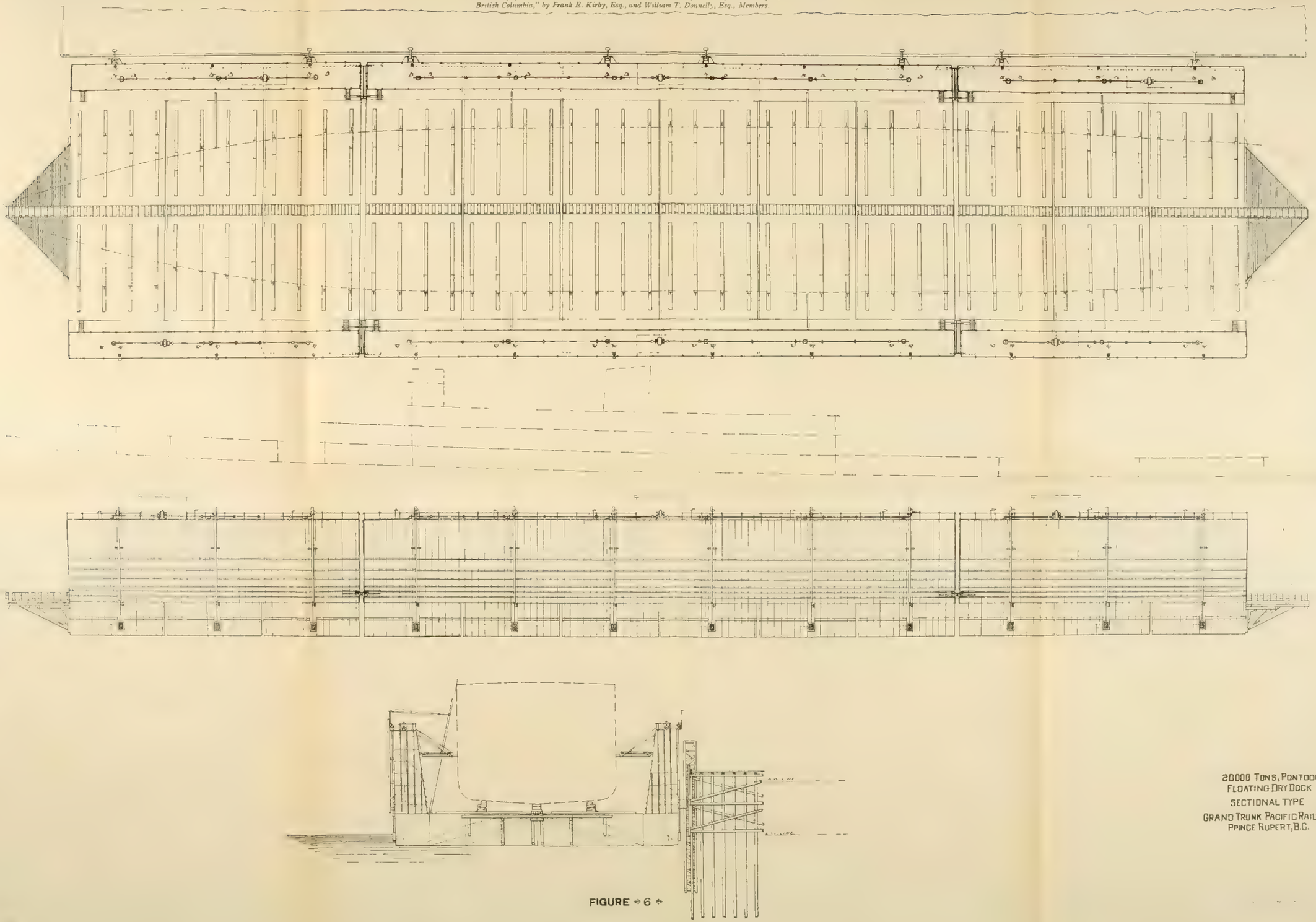


FIGURE → 6 ←

20000 TONS, PONTOON
FLOATING DRY DOCK
SECTIONAL TYPE
GRAND TRUNK PACIFIC RAILWAY
PRINCE RUPERT, B.C.

To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Frank E. Kirby, Esq., and William T. Donnelly, Esq., Members.

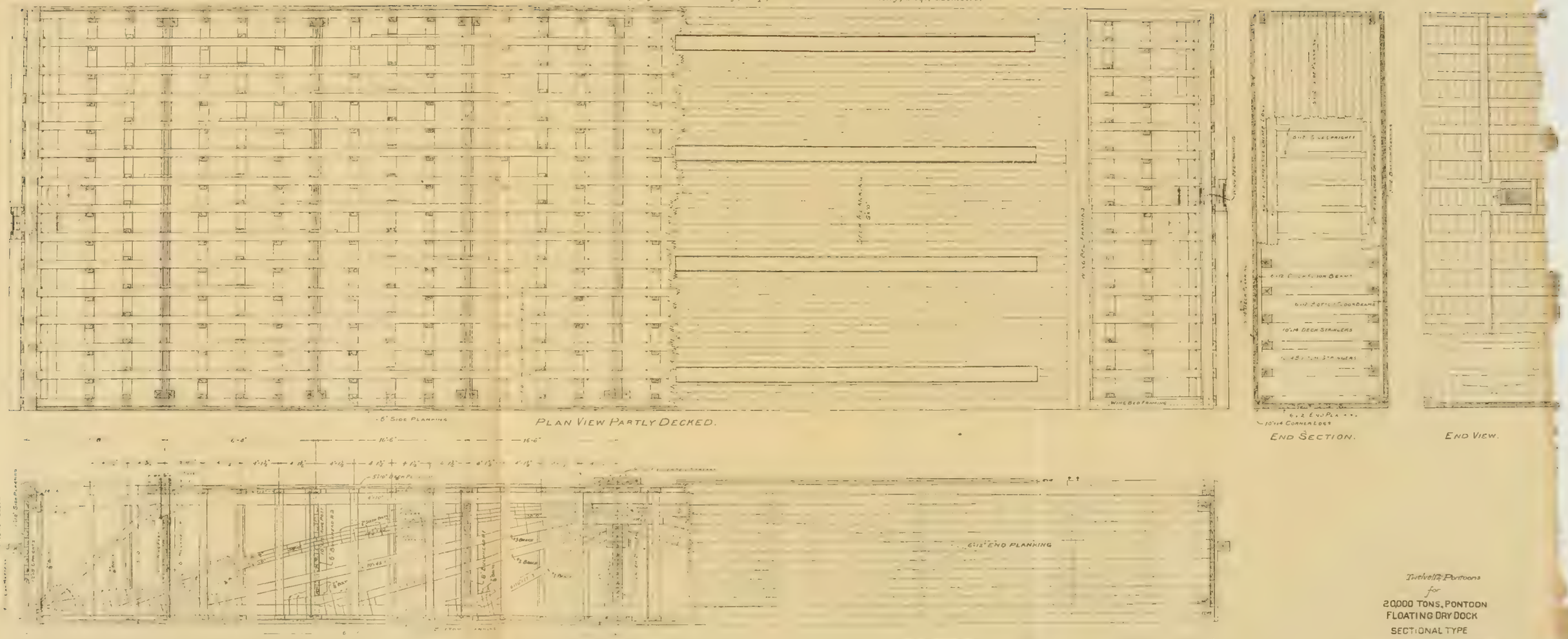
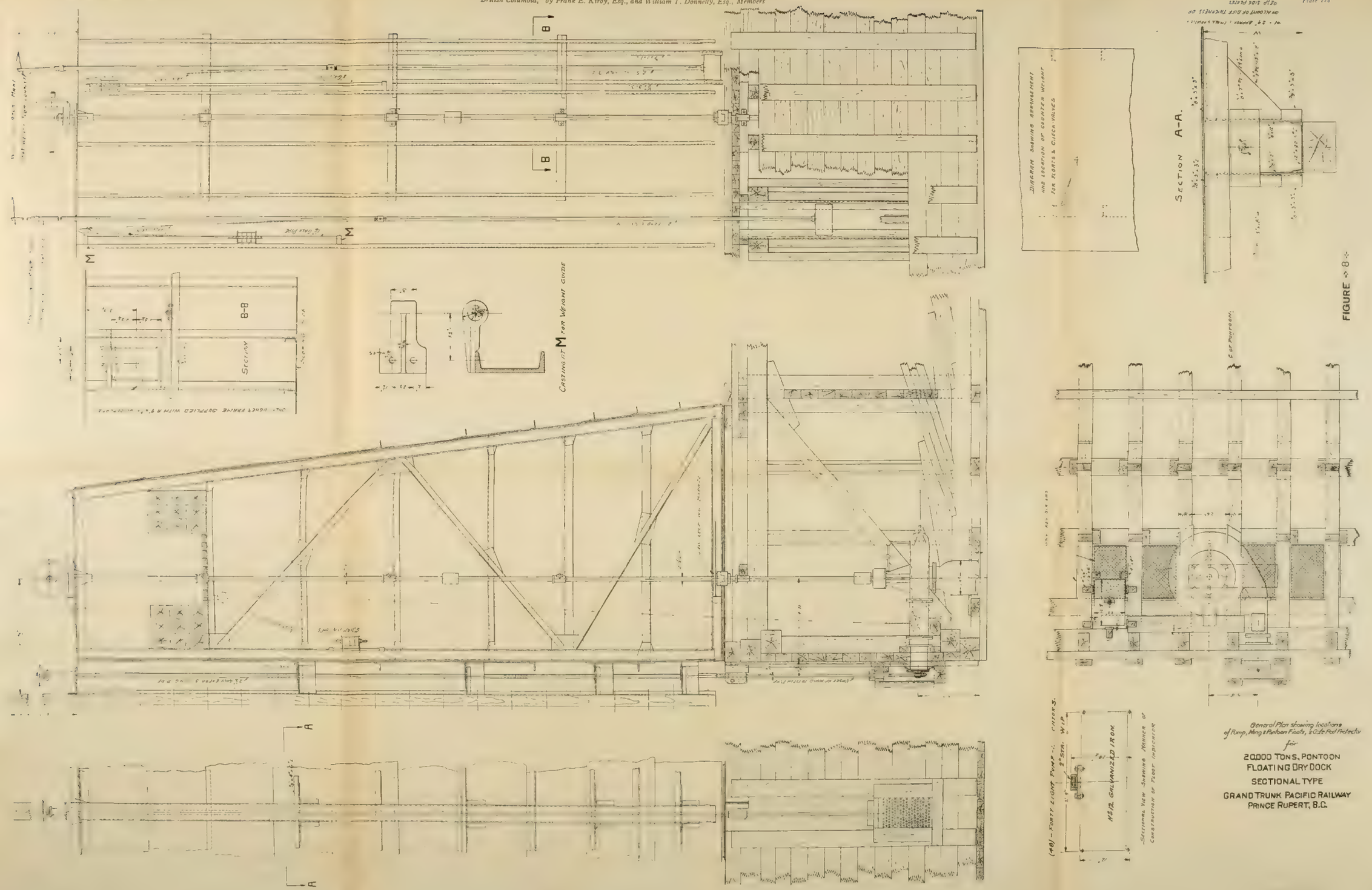


FIGURE → 7 ←

Twelve (12) Pontoons
for
20,000 TONS, PONTOON
FLOATING DRY DOCK
SECTIONAL TYPE
GRAND TRUNK PACIFIC RAILWAY
PRINCE RUPERT, B.C.

To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Franz E. Kirby, Esq., and William T. Donnelly, Esq., Members



General Plan showing locations of Pump, Ming & Pontoon Floats, & Side Rail Protector

for

20,000 TONS, PONTOON FLOATING DRY DOCK

SECTIONAL TYPE

GRAND TRUNK PACIFIC RAILWAY
PRINCE RUPERT, B.C.

To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Frank E. Kirby, Esq., and William T. Donnelly, Esq., Members.

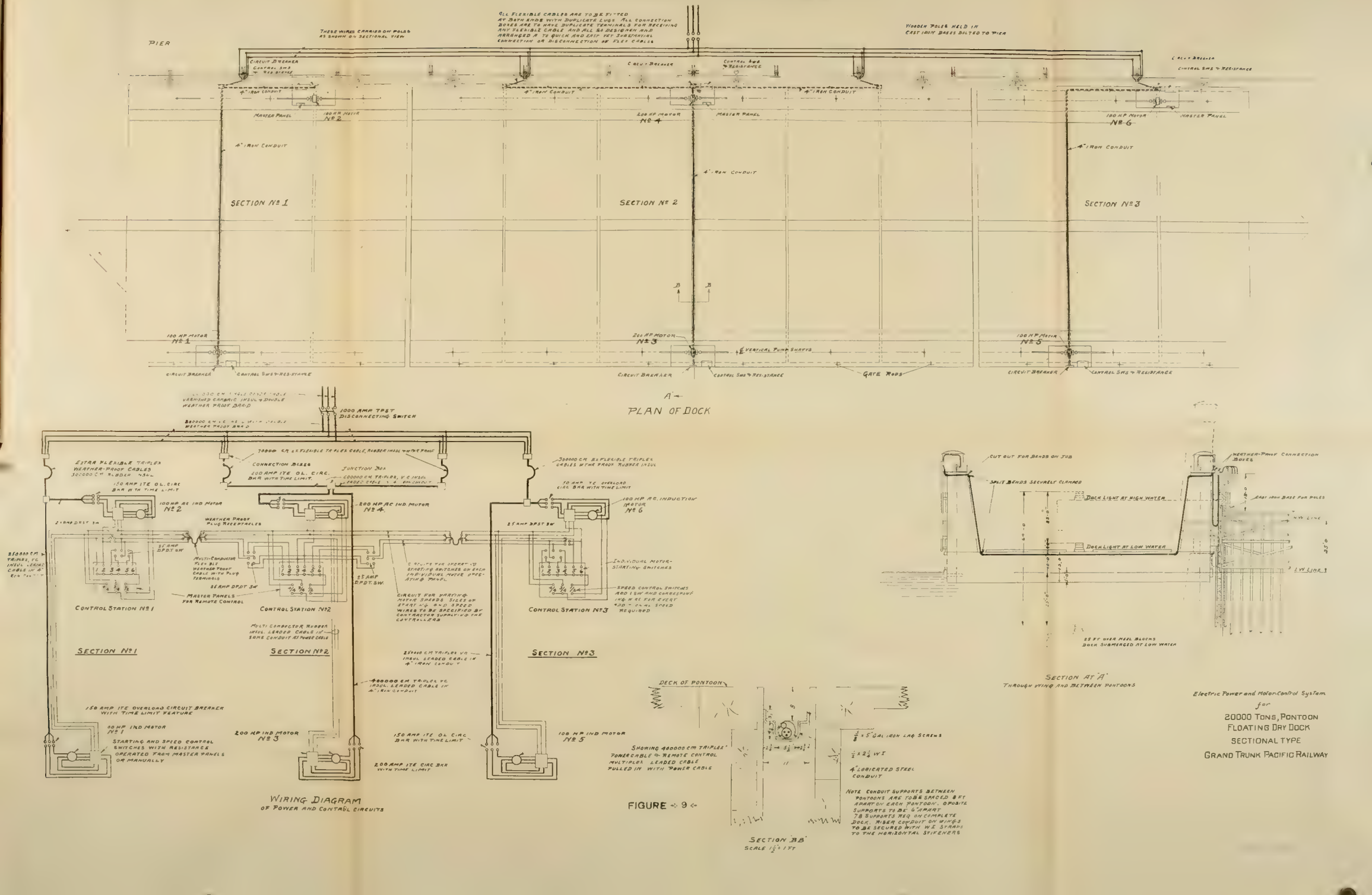
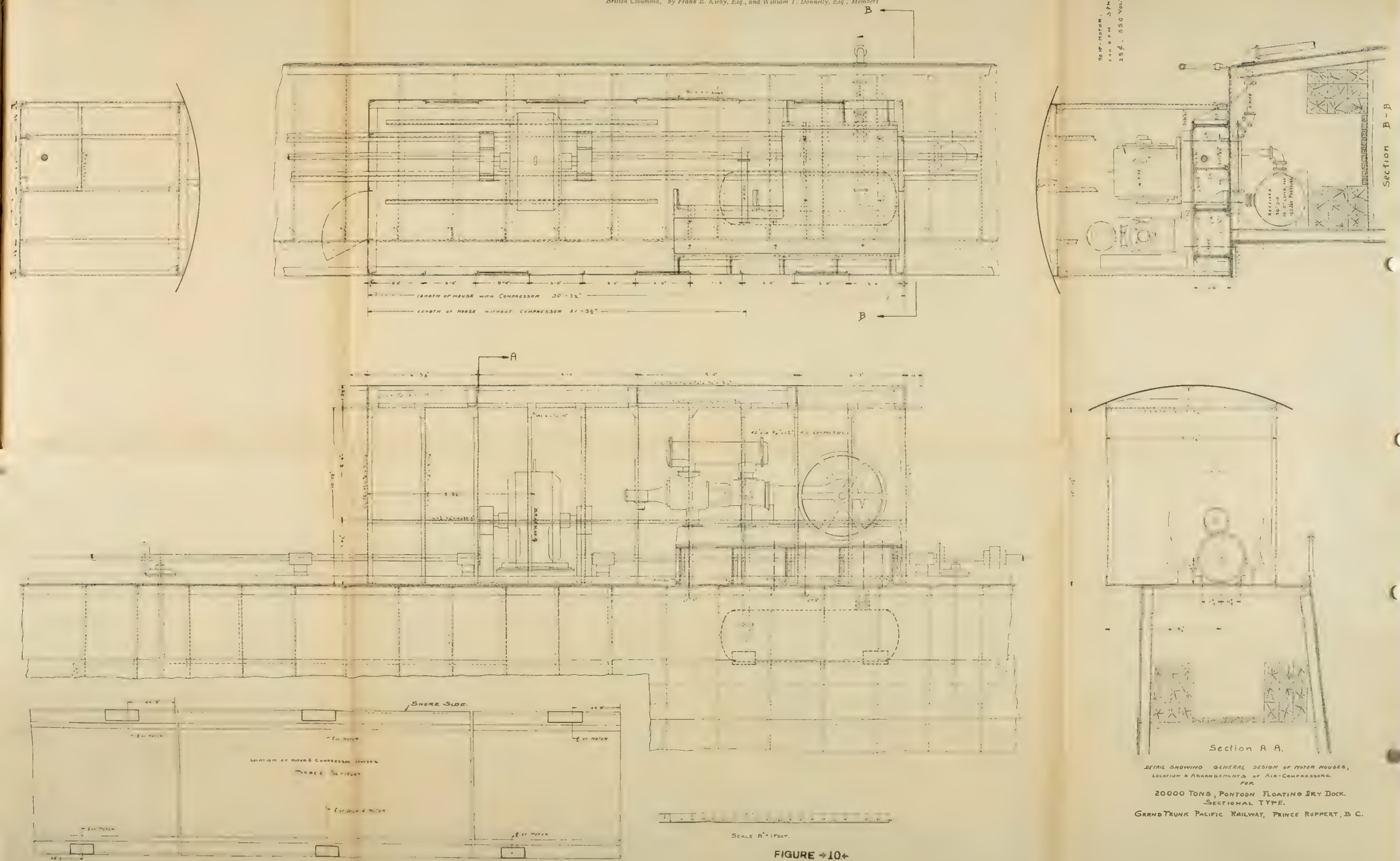


FIGURE 9

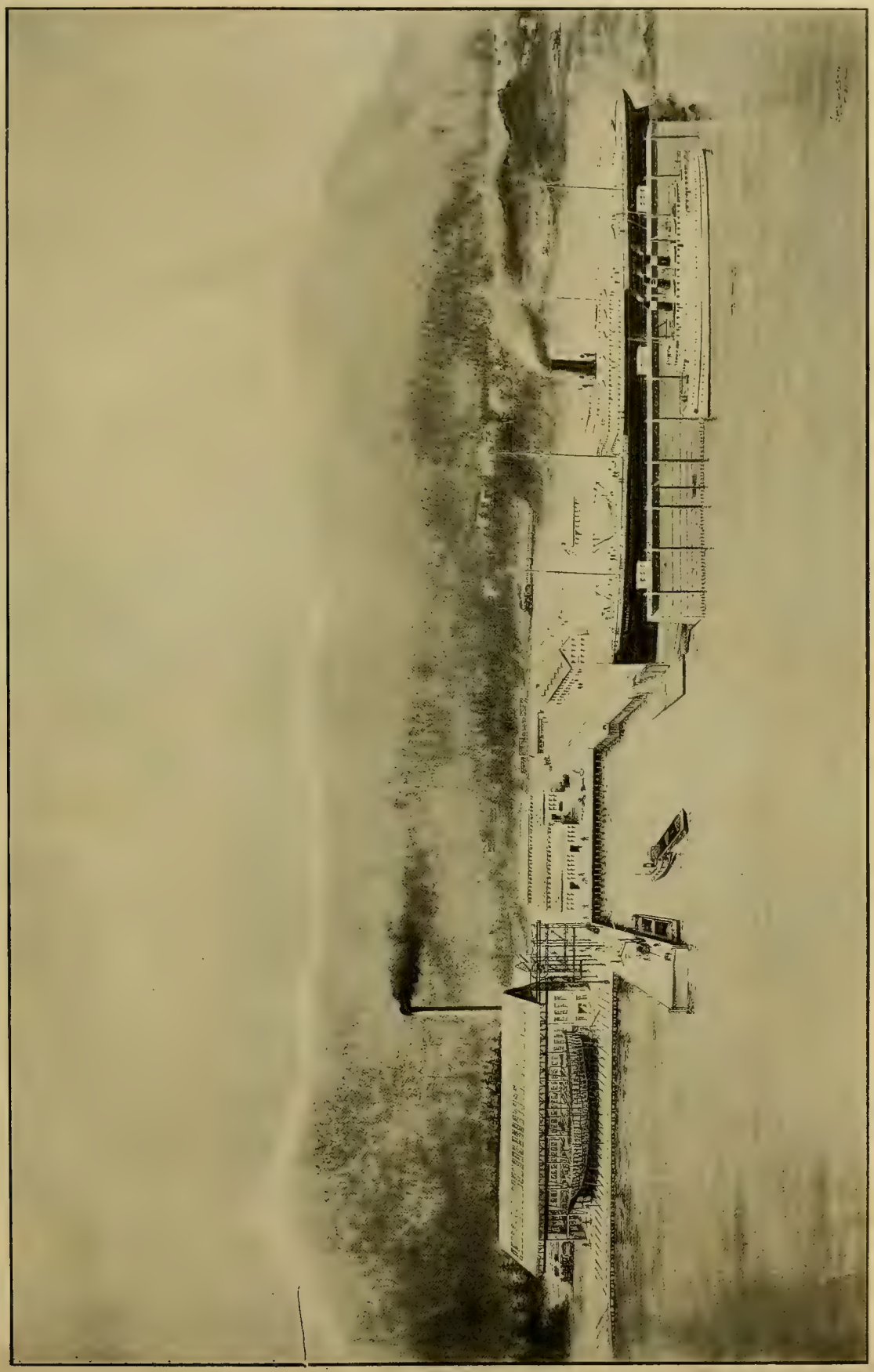
To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Frank E. Kirby, Esq., and William T. Donnelly, Esq., Members



DETAIL SHOWING GENERAL DESIGN OF MOTOR HOUSES, LOCATION & ARRANGEMENTS OF AIR-COMPRESSORS.
FOR
20000 TONS, PONTOON FLOATING DRY DOCK.
SECTIONAL TYPE.
GRAND TRUNK PACIFIC RAILWAY, PRINCE RUPPERT, B.C.

FIGURE → 10 ←

To illustrate paper on "The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia," by Frank E. Kirby, Esq., and William T. Donnelly, Esq., Members.



SHIP REPAIR AND SHIP BUILDING PLANT AT PRINCE RUPERT, B. C., AS IT WILL APPEAR WHEN COMPLETED.

To illustrate paper on "Heavy-Oil Engines for Marine Propulsion," by G. C. Davison, Esq., Member.

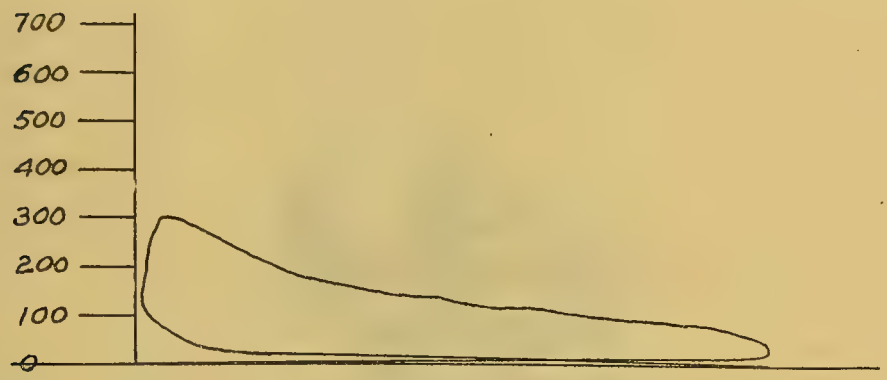


FIG. I

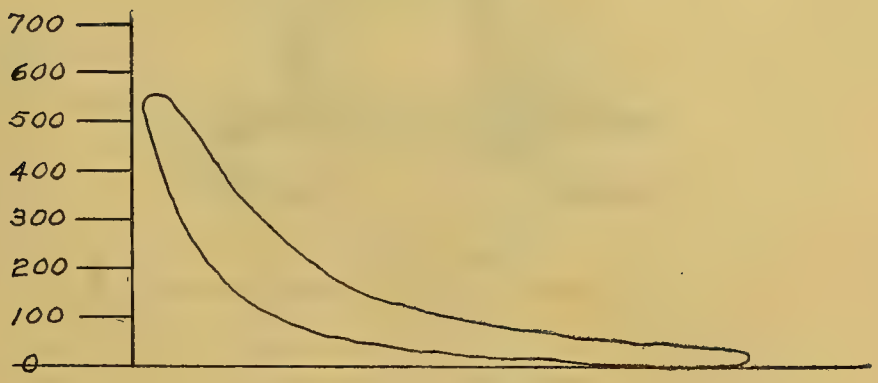
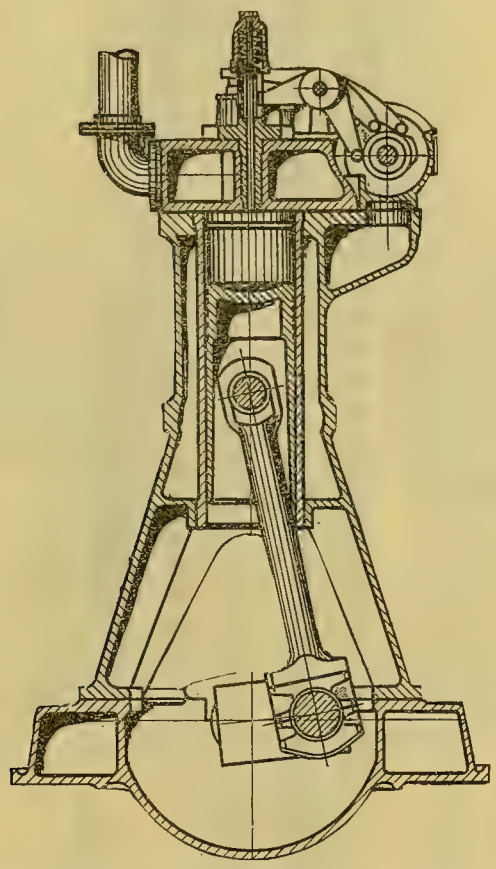


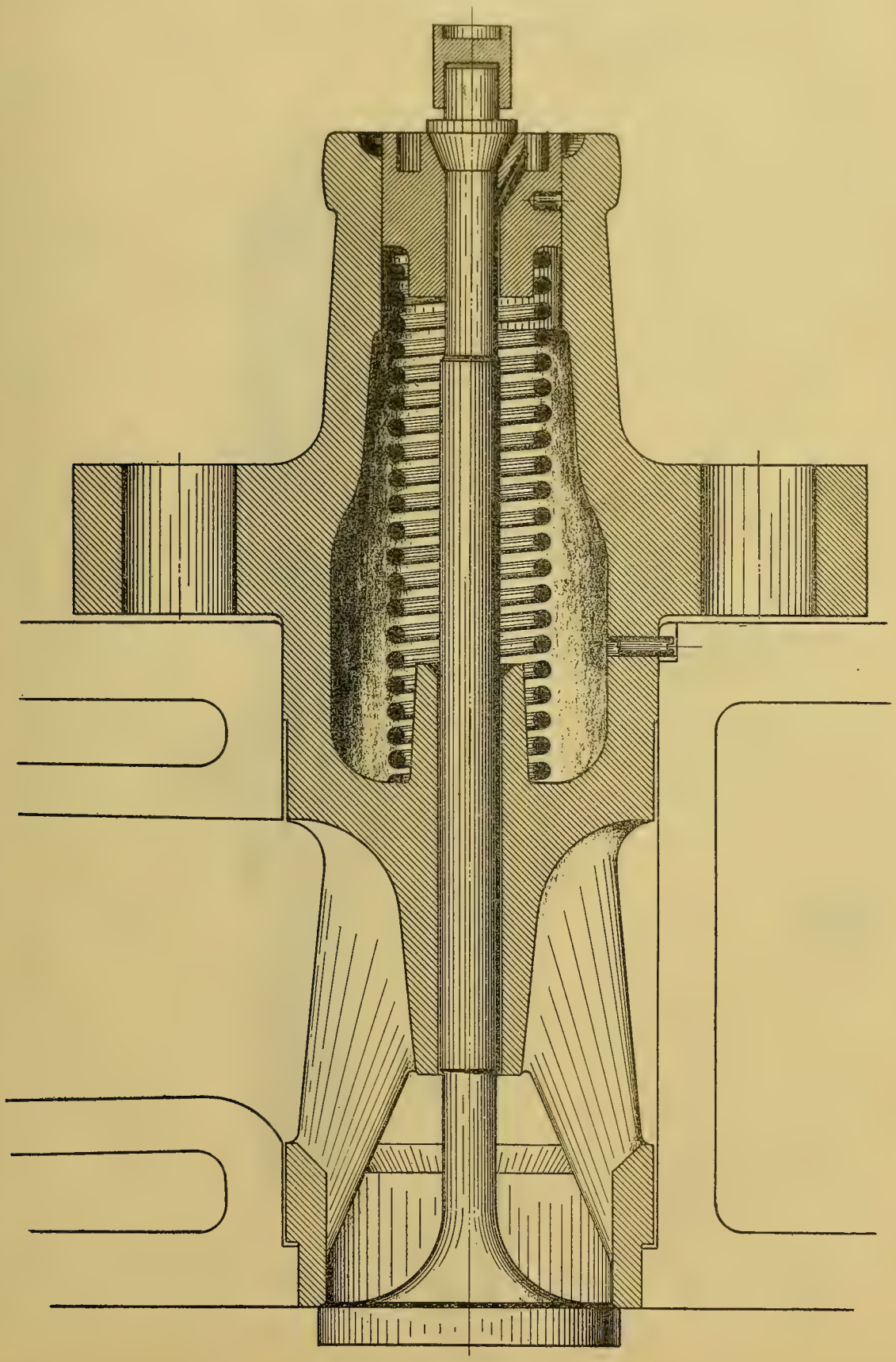
FIG. II

To illustrate paper on "Heavy-Oil Engines for Marine Propulsion," by G. C. Davison, Esq., Member.



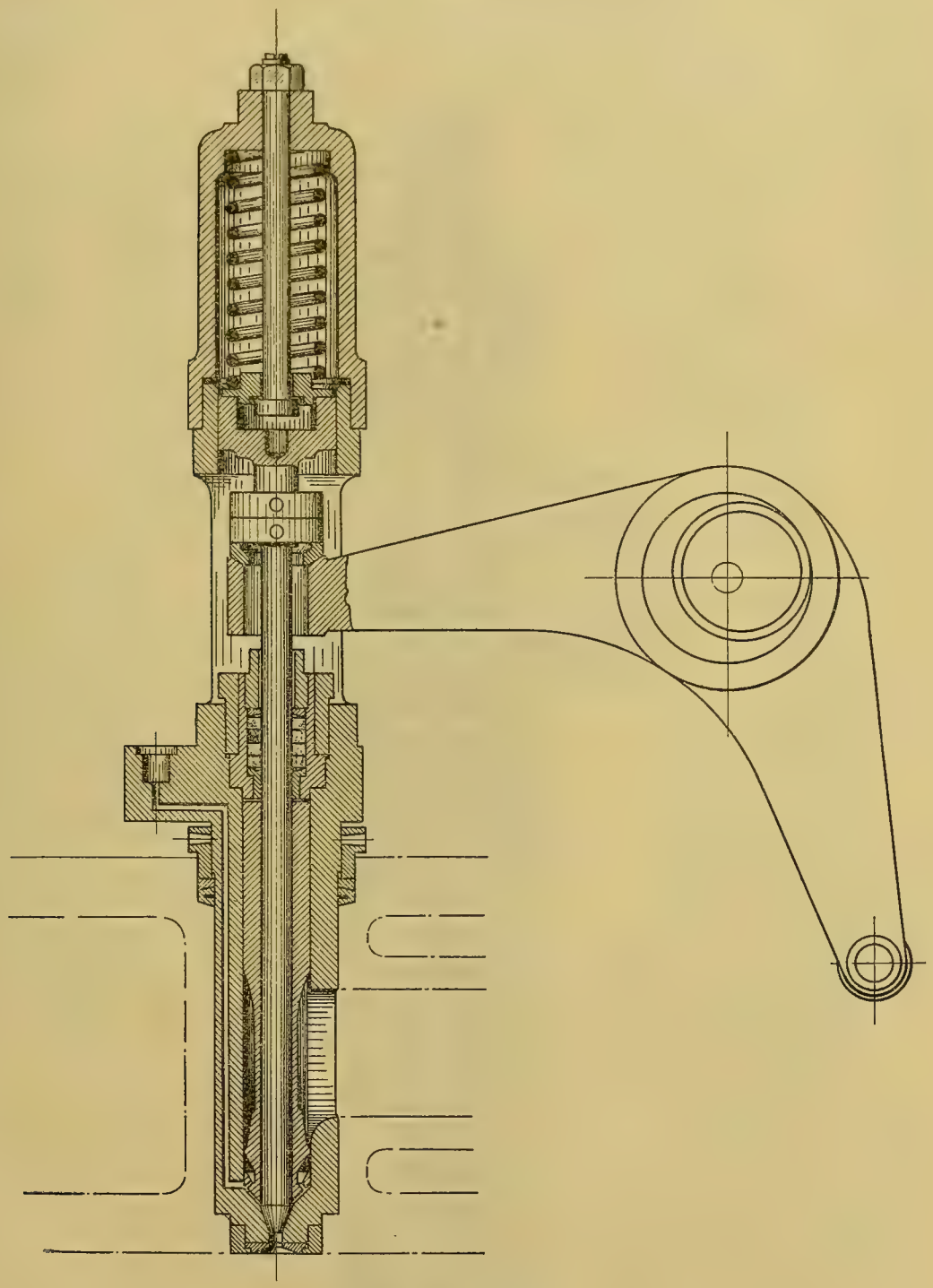
TRANSVERSE SECTION OF A TYPICAL DIESEL ENGINE.

To illustrate paper on "Heavy-Oil Engines for Marine Propulsion," by G. C. Davison, Esq., Member.



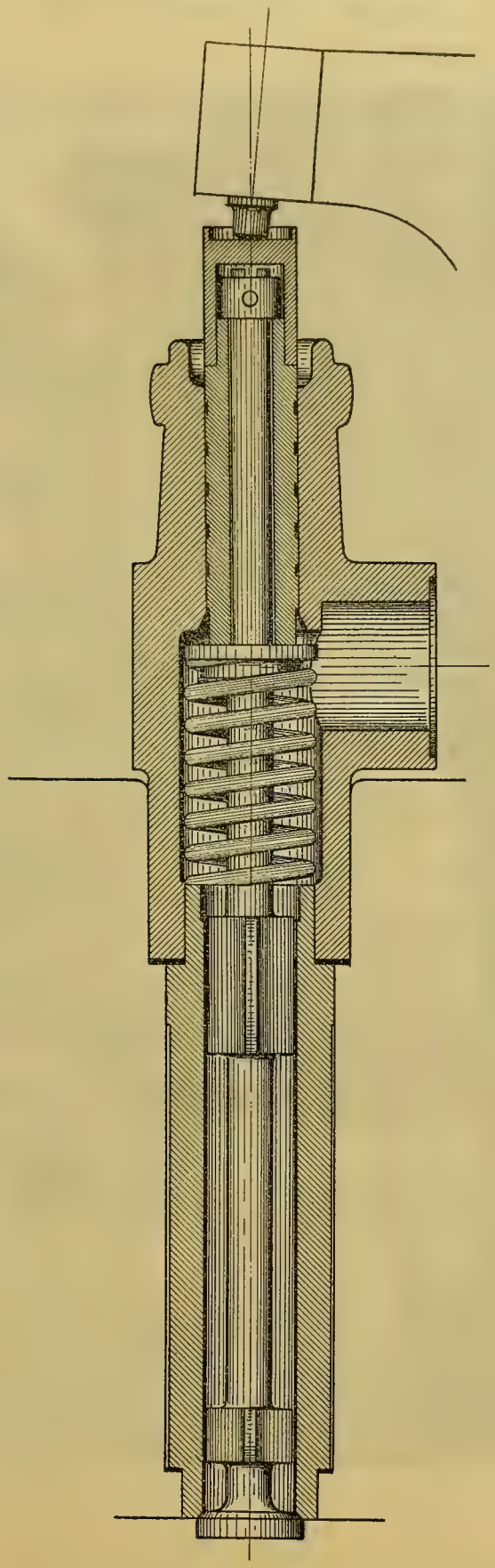
SCAVENGING VALVE.

To illustrate paper on "Heavy-Oil Engines for Marine Propulsion," by G. C. Davison, Esq., Member.



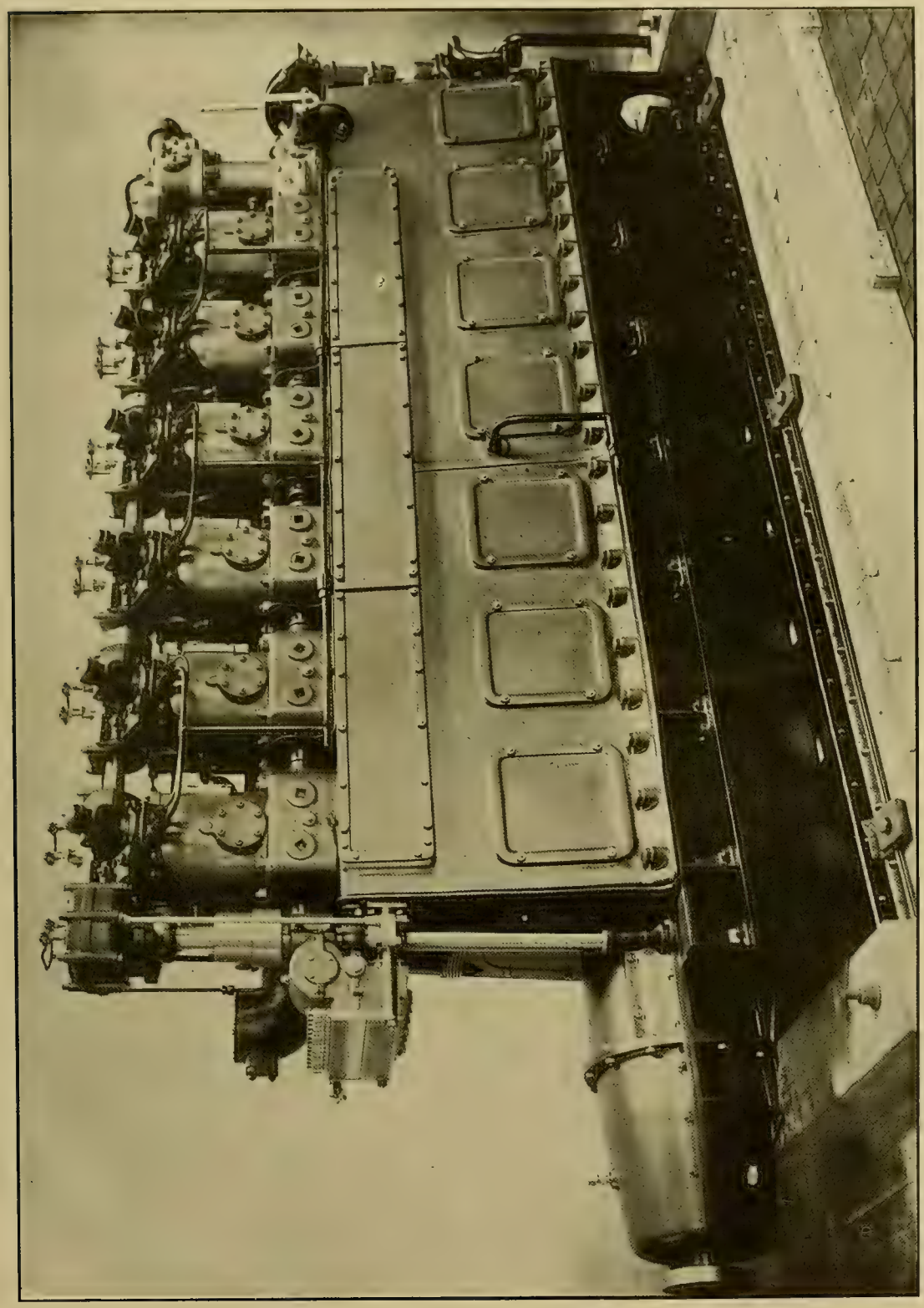
FUEL SPRAY VALVE.

To illustrate paper on "Heavy-Oil Engines for Marine Propulsion," by G. C. Davison, Esq., Member.



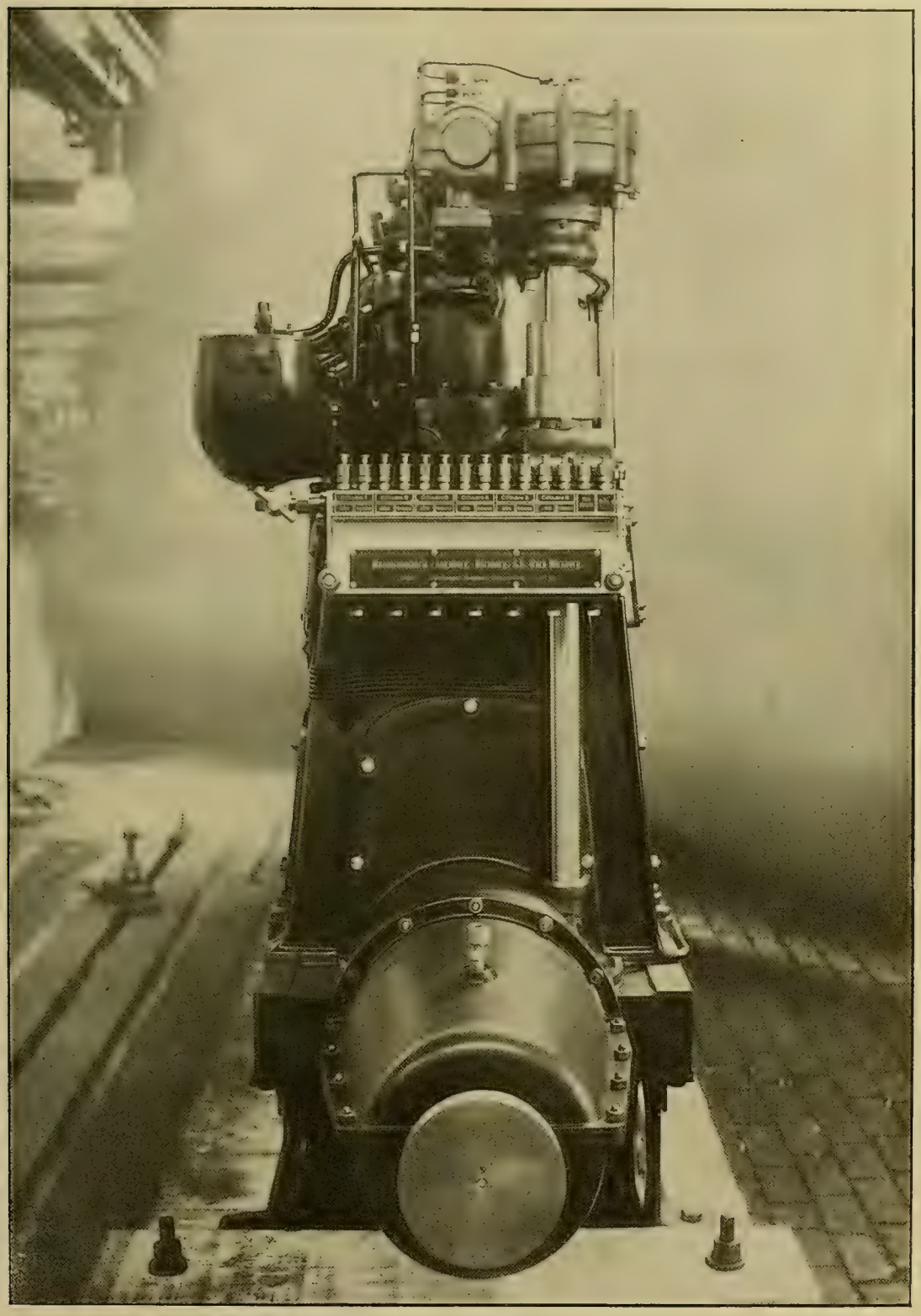
AIR STARTING VALVE.

To illustrate paper on "Heavy-Oil Engines for Marine Propulsion," by G. C. Davison, Esq., Member.



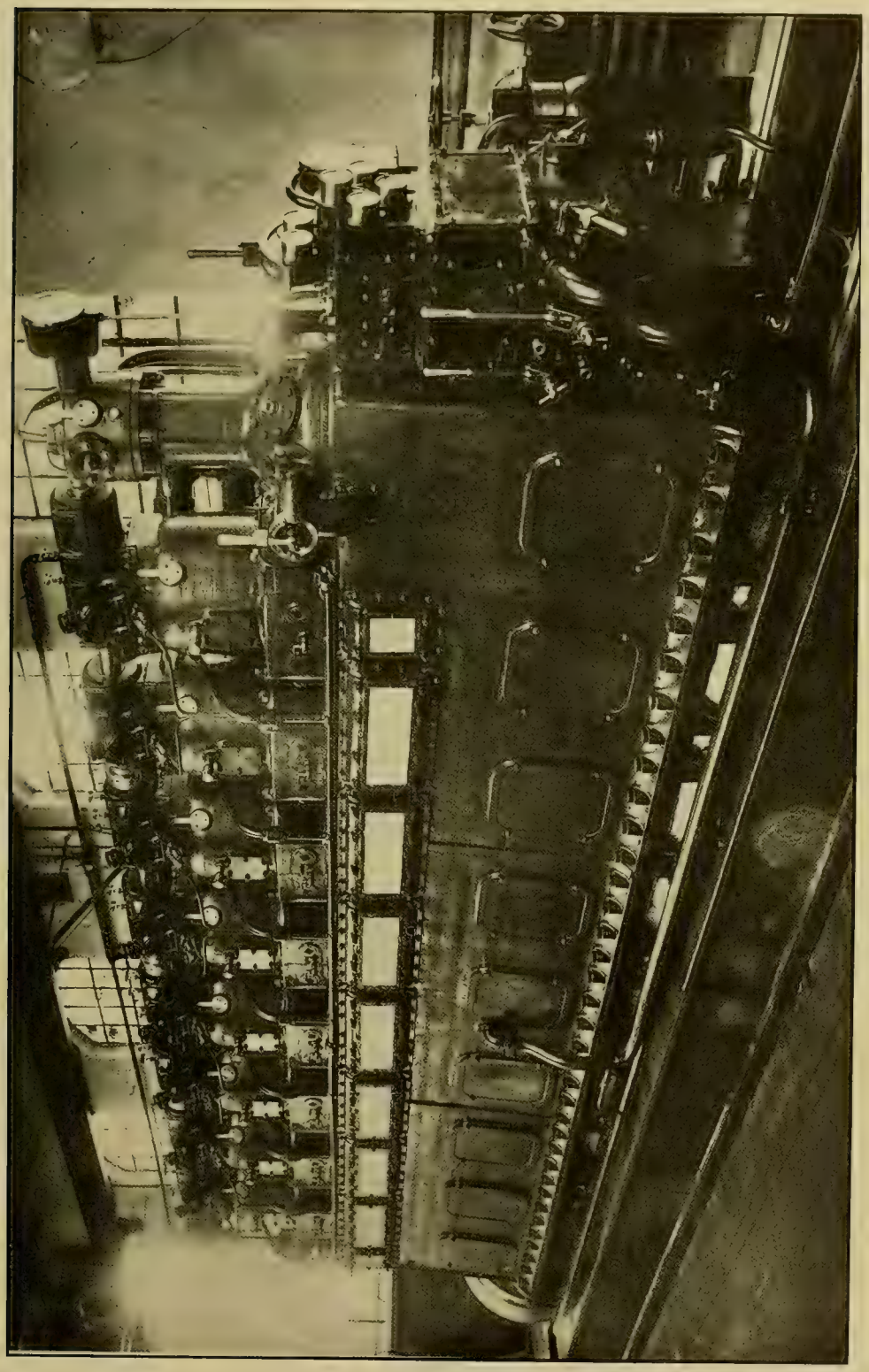
150 H. P. Two Cycle Reversivle Marine Oil Engine, 600 R. P. M.

To illustrate paper on "Heavy-Oil Engines for Marine Propulsion," by G. C. Davison, Esq., Member.



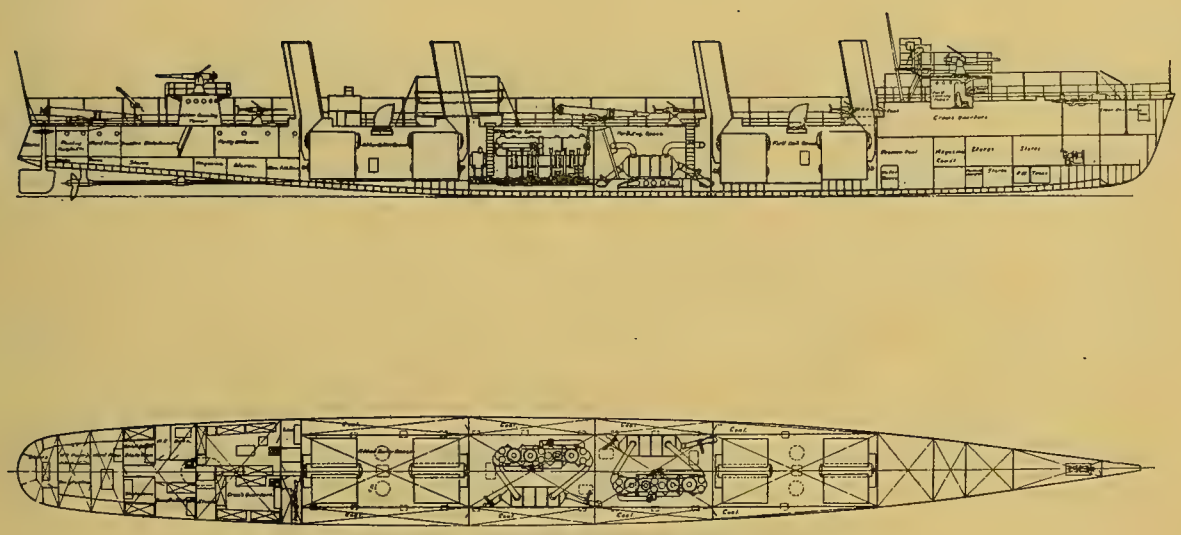
150 H. P. Two Cycle Reversible Marine Oil Engine.

To illustrate paper on "Heavy-Oil Engines for Marine Propulsion," by G. C. Davison, Esq., Member.



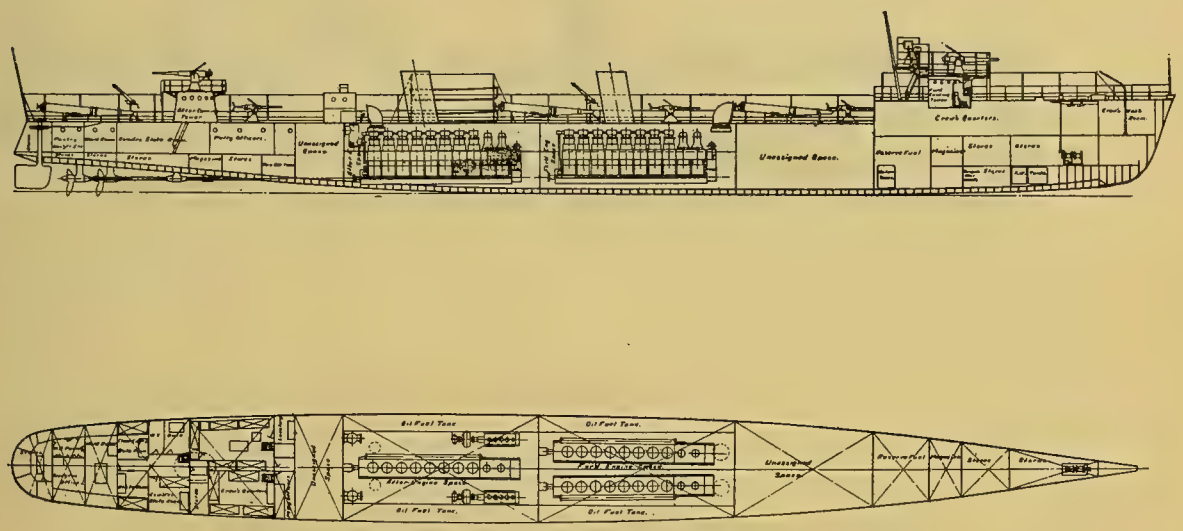
850 H. P. Two Cycle Reversible Marine Oil Engine, 400 R. P. M.

To illustrate paper on "Heavy-Oil Engines for Marine Propulsion," by G. C. Davison, Esq., Member.



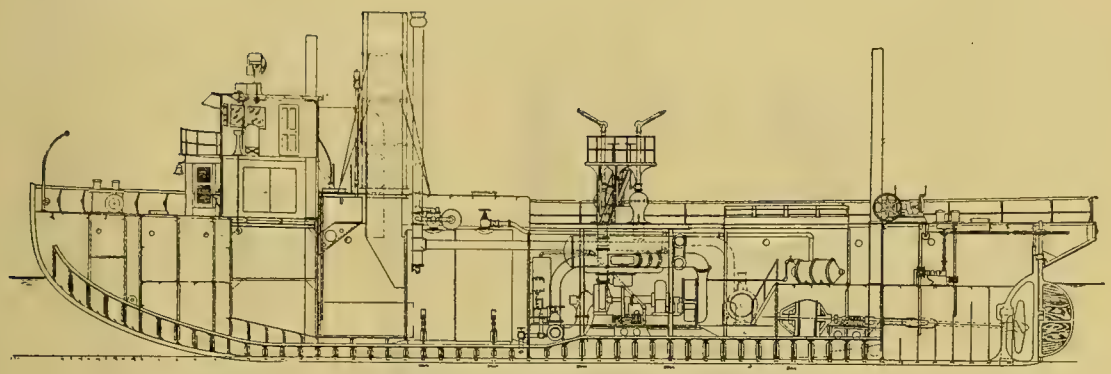
THE PAUL JONES WITH PRESENT STEAM PLANT.

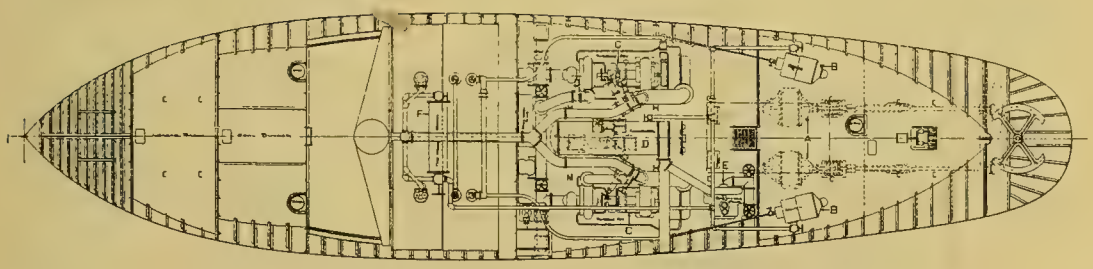
To illustrate paper on "Heavy-Oil Engines for Marine Propulsion," by G. C. Davison, Esq., Member.



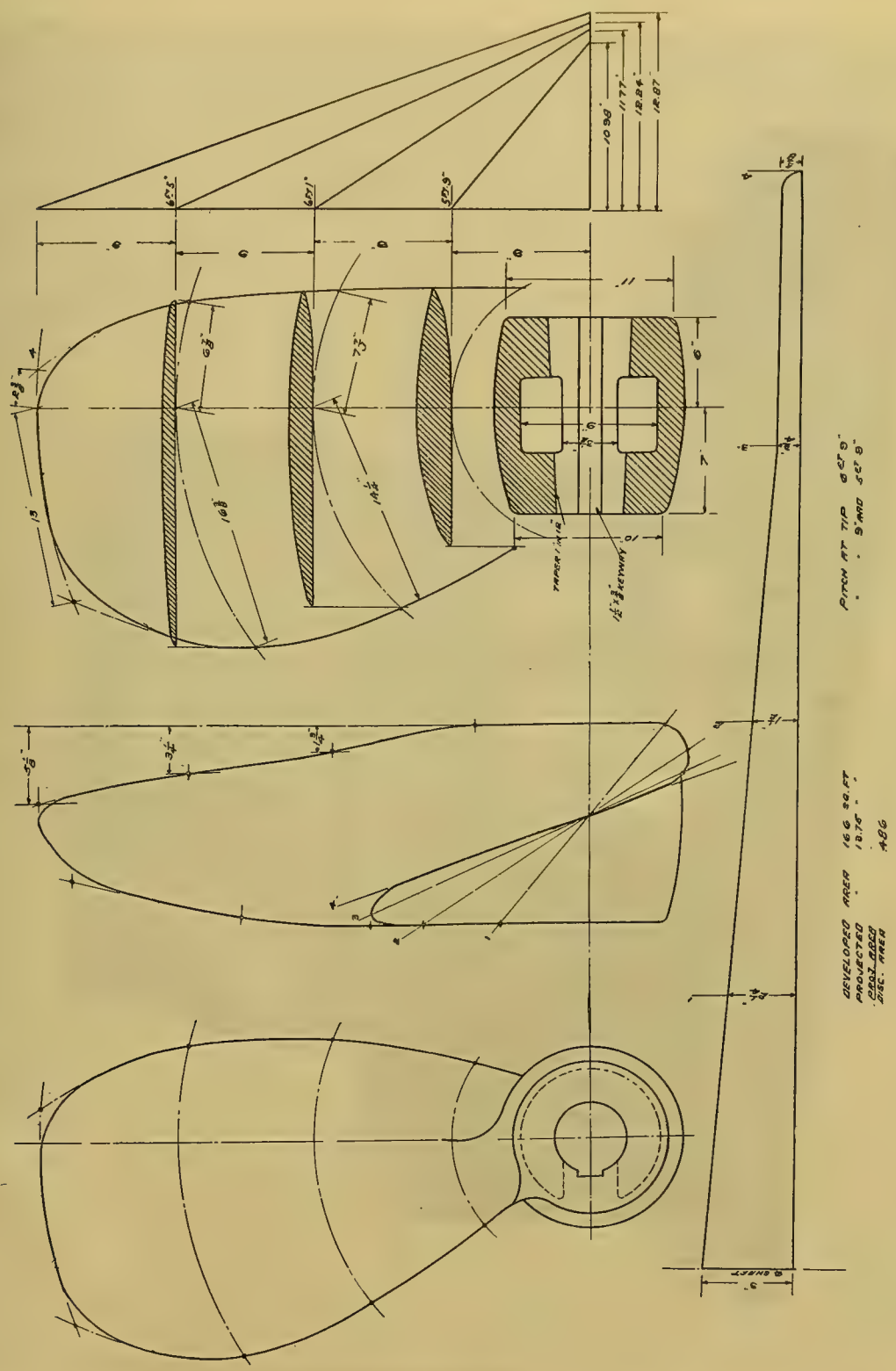
THE PAUL JONES WITH HEAVY-OIL ENGINES.

To illustrate paper on "Automatic Record of Propeller Action in an Electrically Propelled Vessel," by W. L. R. Emmet, Esq., Member.

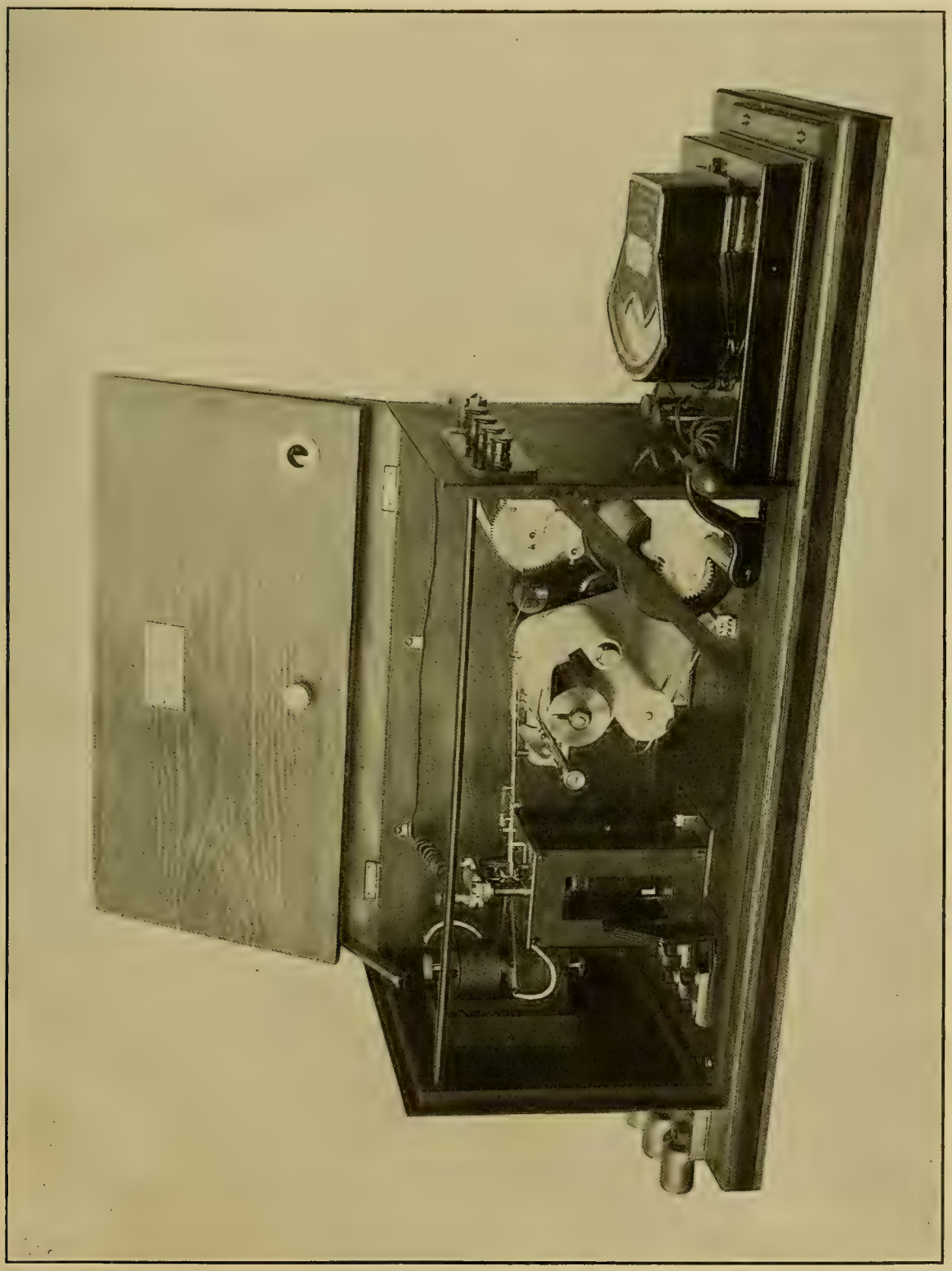




To illustrate paper on "Automatic Record of Propeller Action in an Electrically Propelled Vessel," by W. L. R. Emmet, Esq., Member.

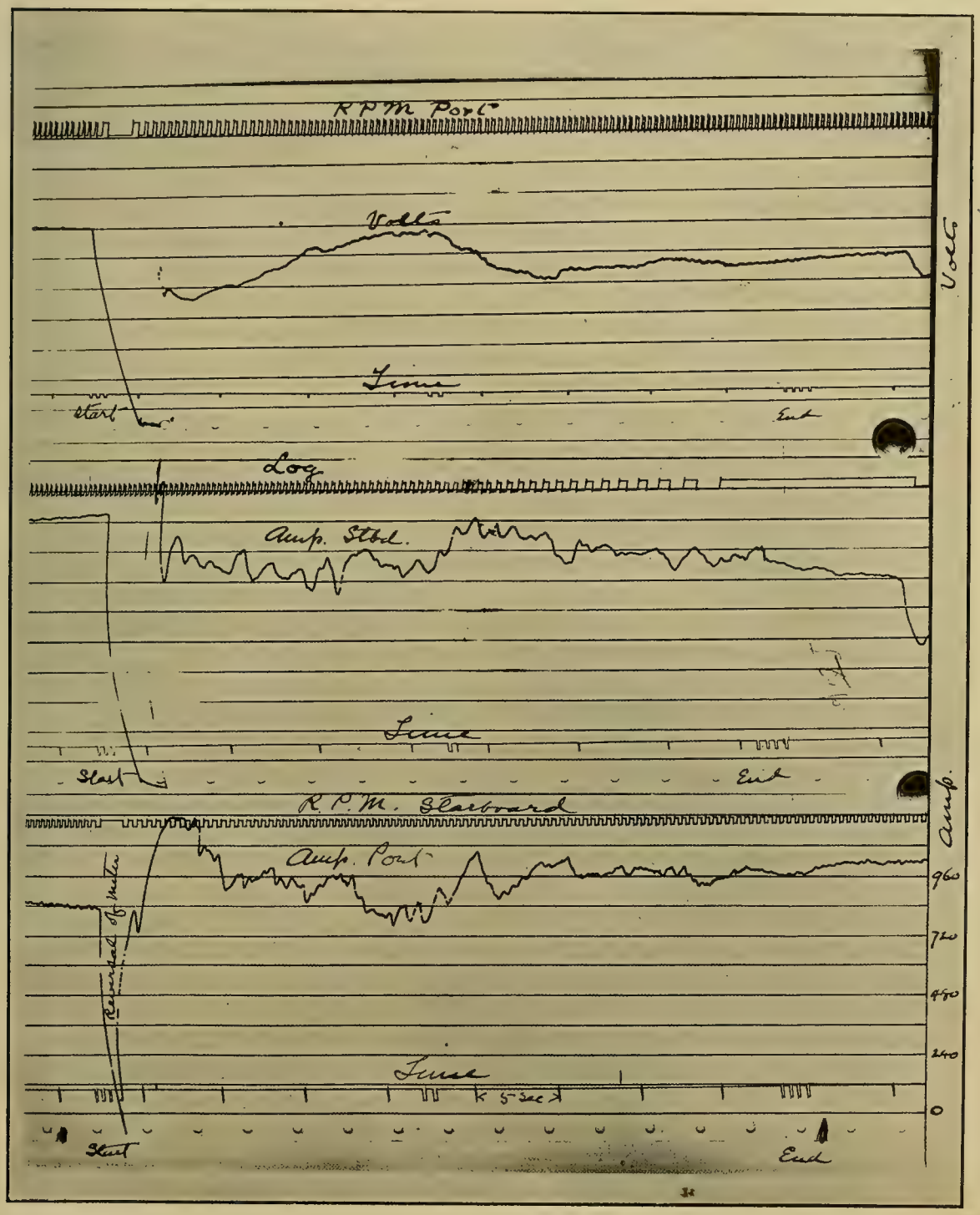


To illustrate paper on "Automatic Record of Propeller Action in an Electrically Propelled Vessel," by W. L. R. Emmet, Esq., Member.

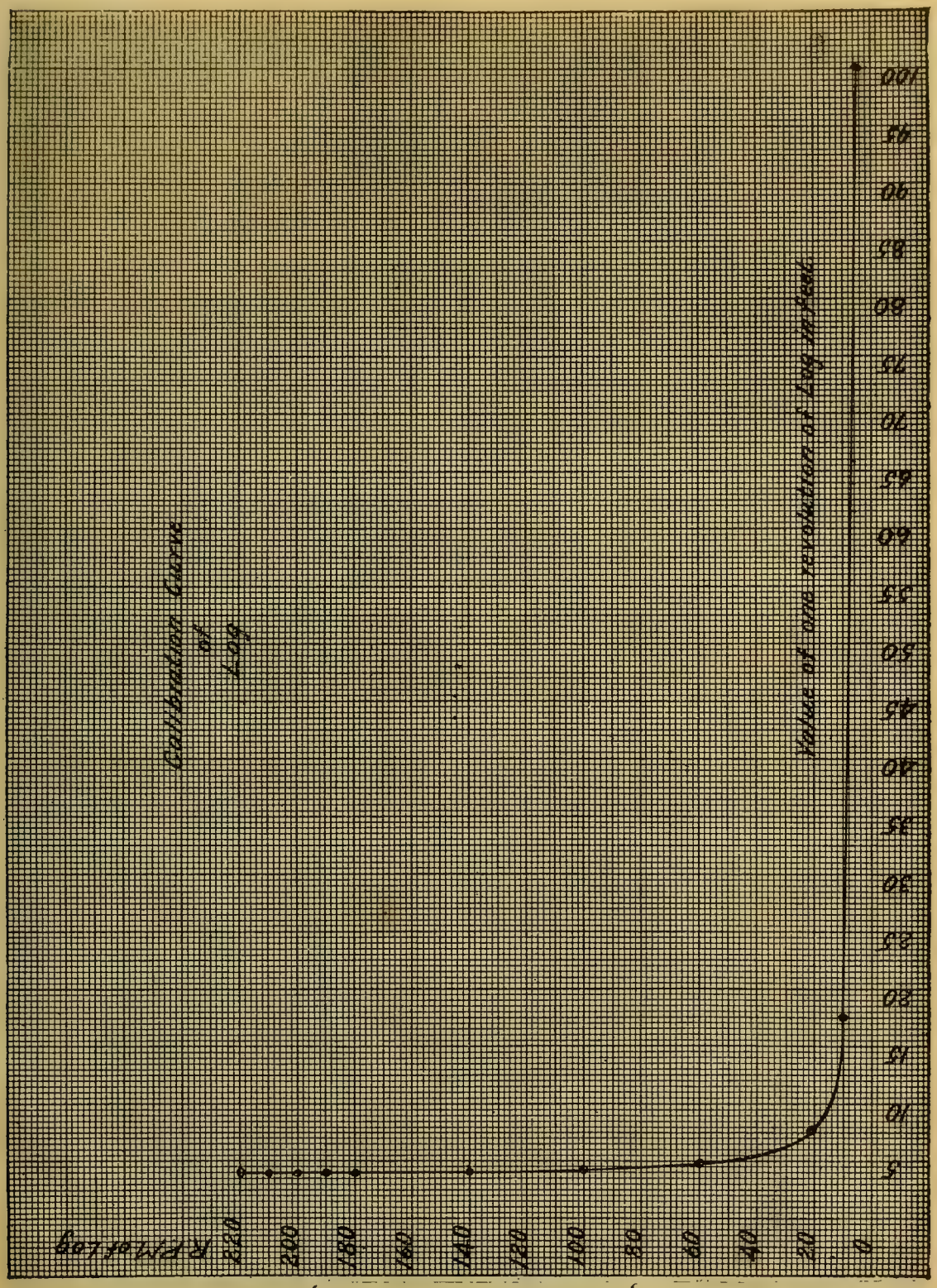


Graphic Recording Machine.

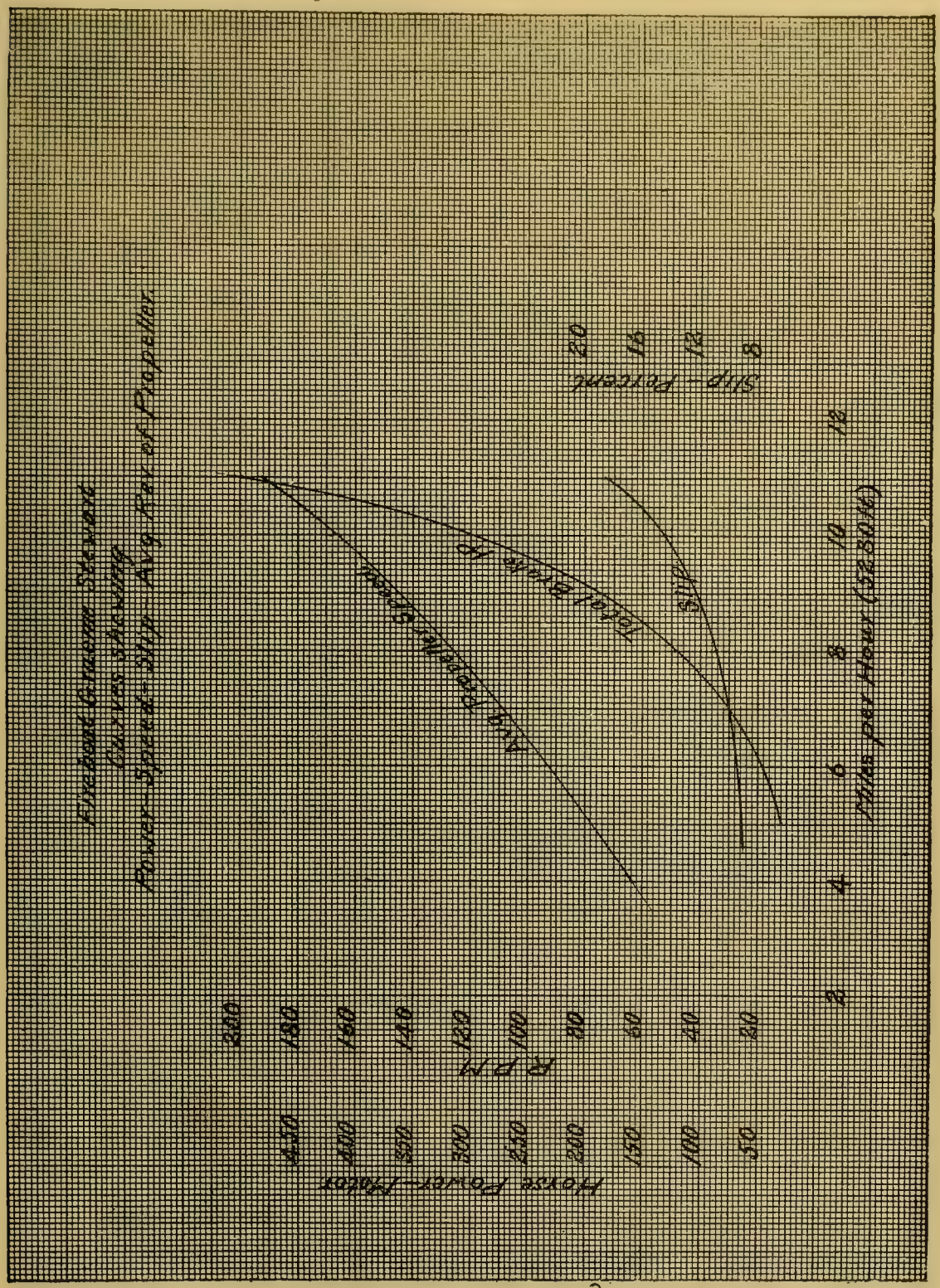
To illustrate paper on "Automatic Record of Propeller Action in an Electrically Propelled Vessel," by W. L. R. Emmet, Esq., Member.



To illustrate paper on "Automatic Record of Propeller Action in an Electrically Propelled Vessel," by W. L. R. Emmet, Esq., Member.



To illustrate paper on "Automatic Record of Propeller Action in an Electrically Propelled Vessel," by W. L. R. Emmet, Esq., Member.



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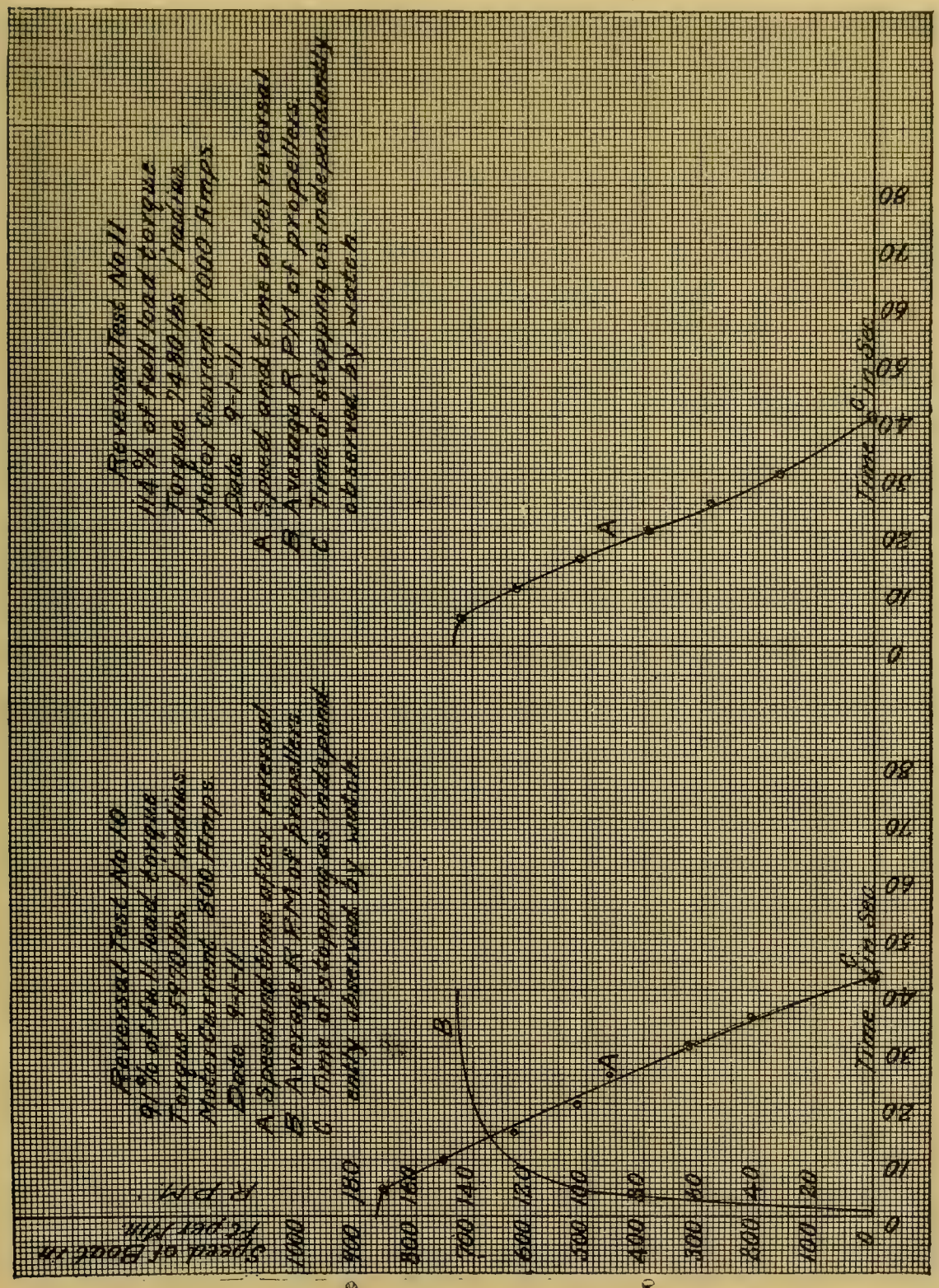

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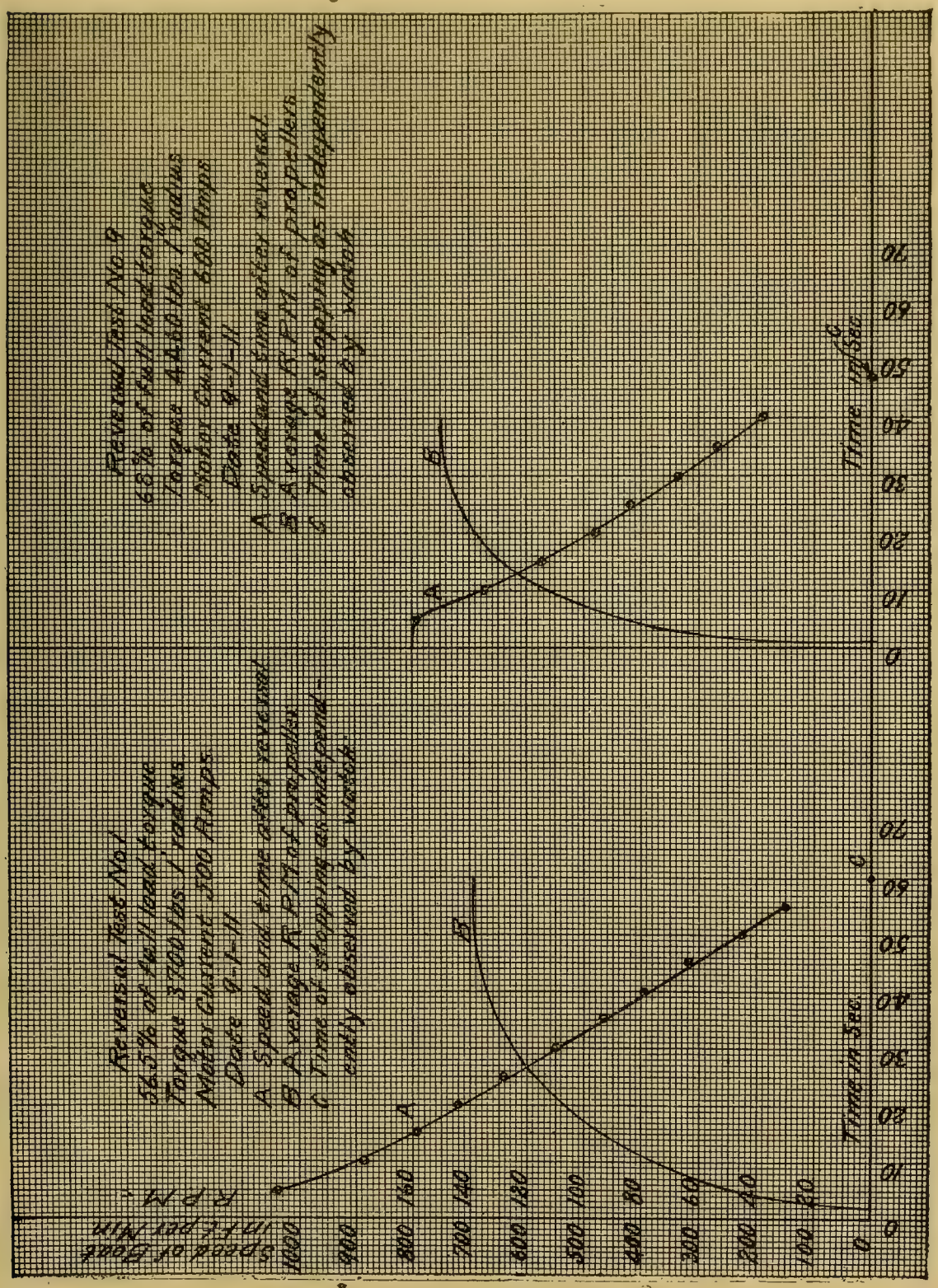

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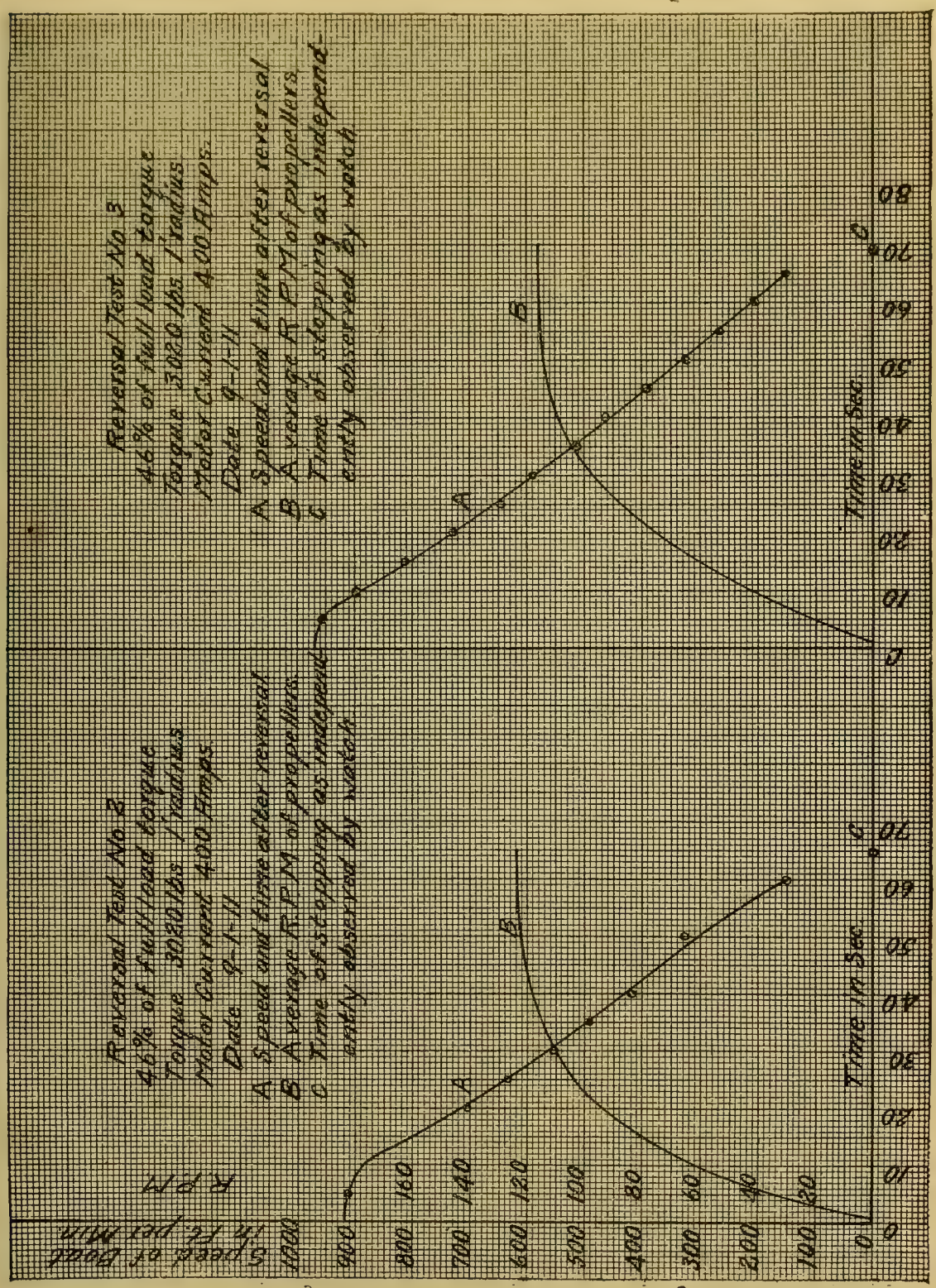

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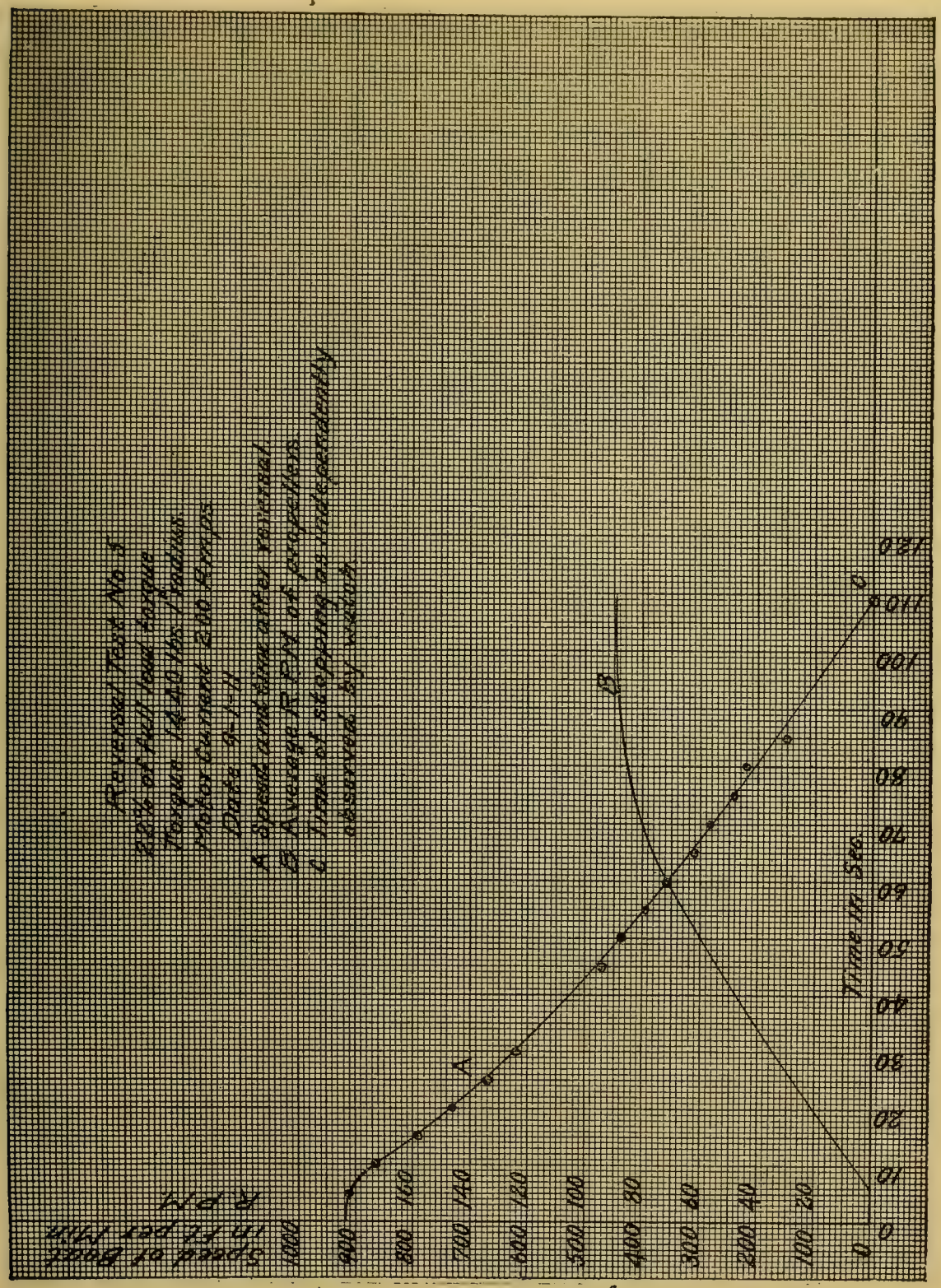

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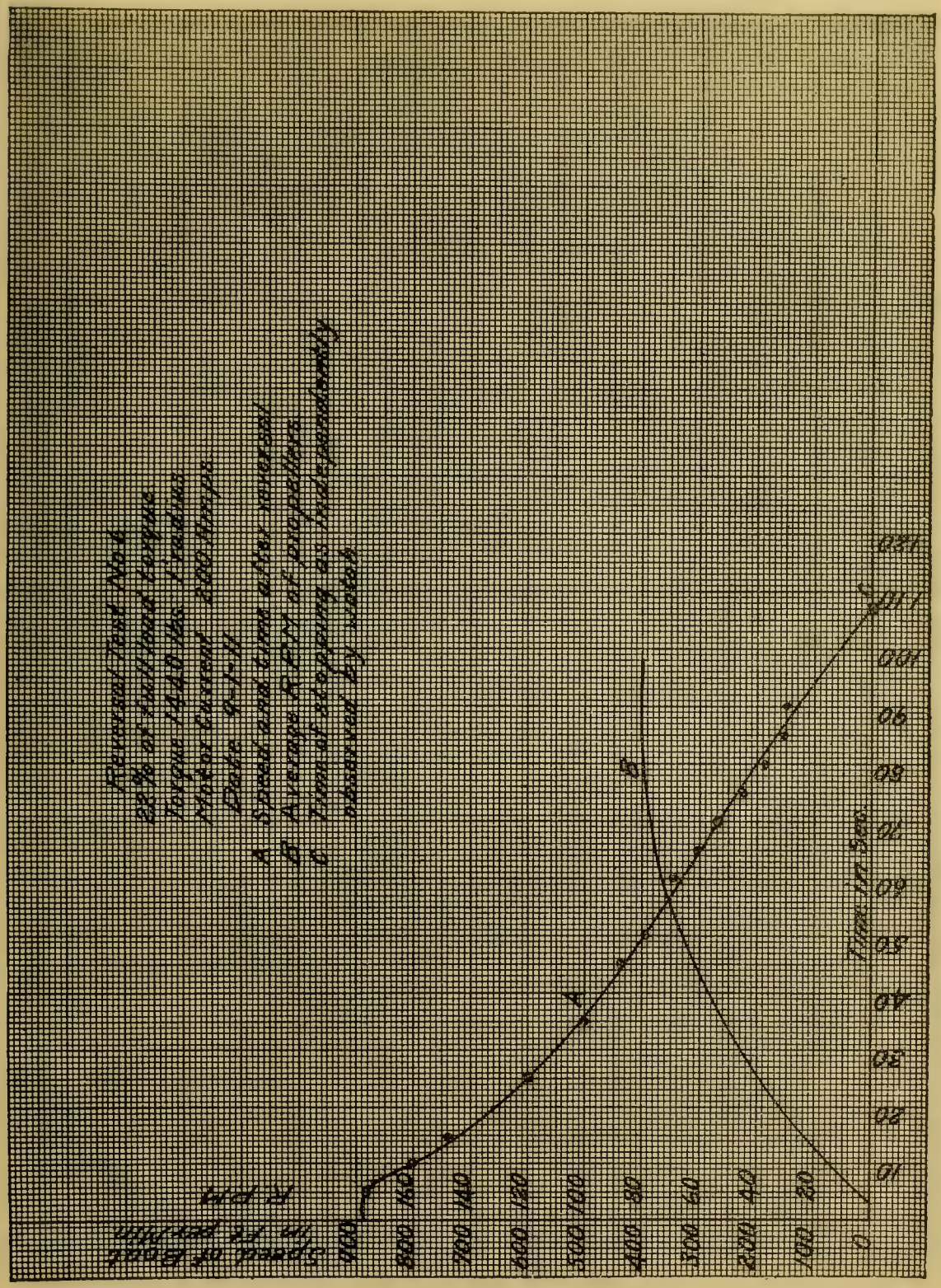

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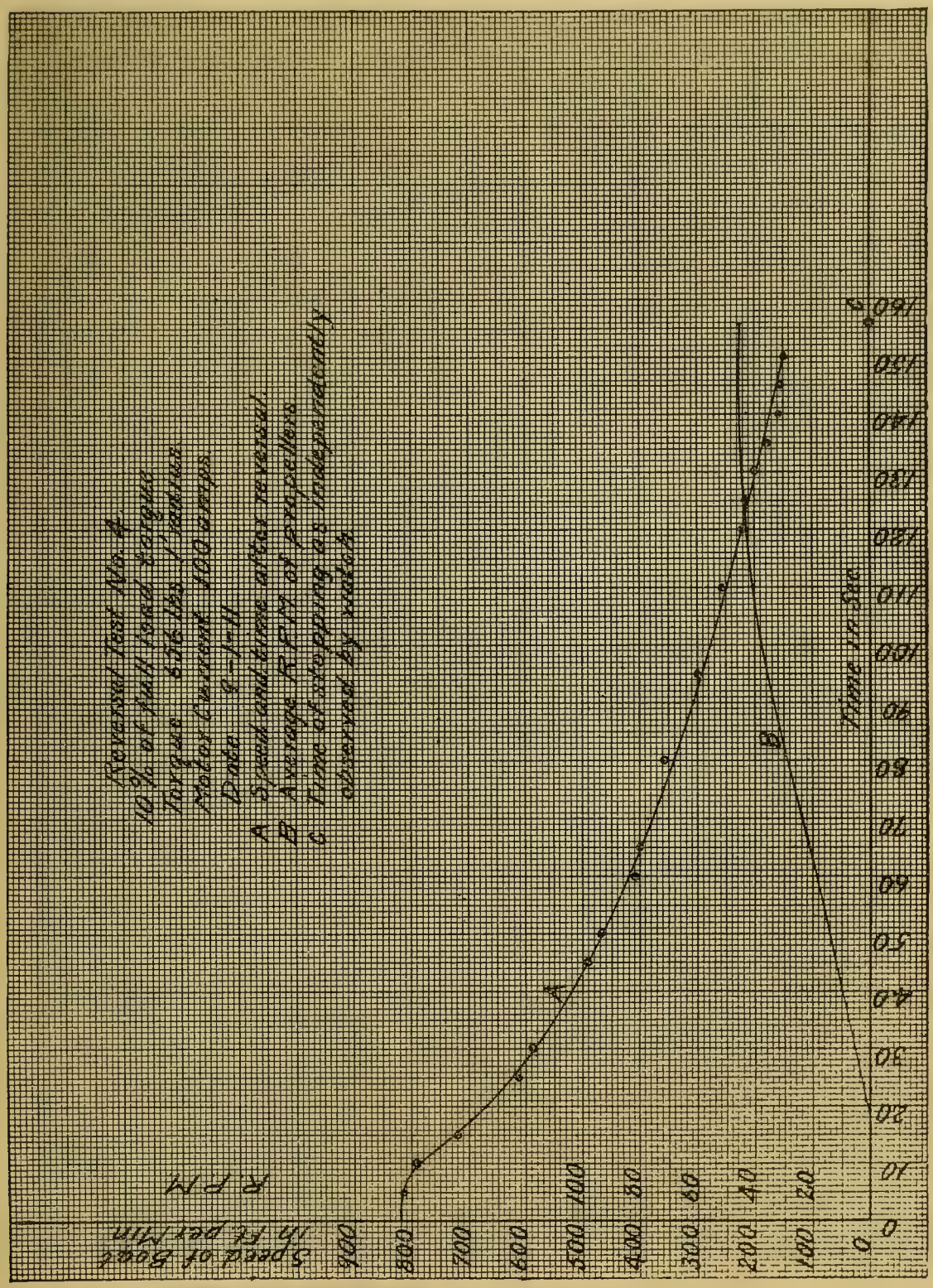

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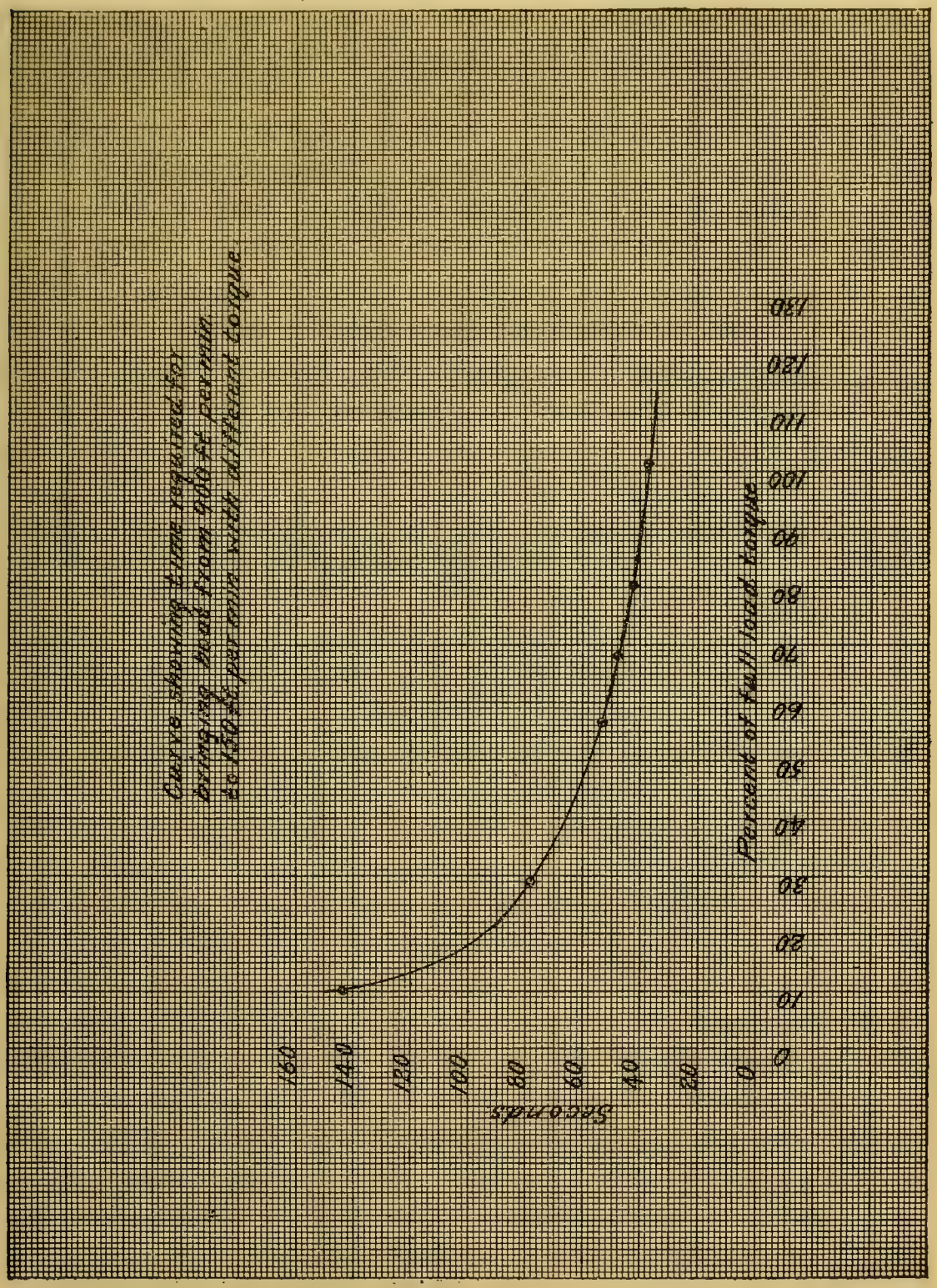

To illustrate paper on "Some Applications of the Principles of Naval Architecture to Aeronautics," by Naval Constructor William McEntee, U. S. N., Member.

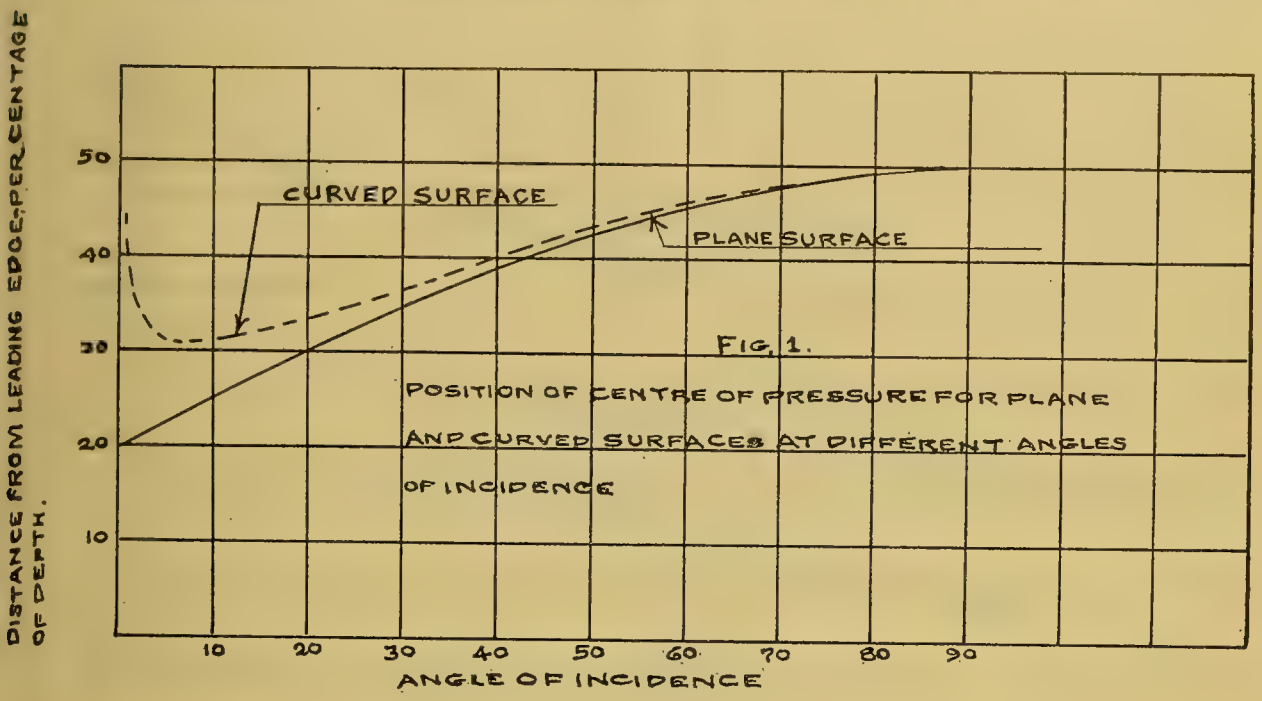

FIG. 1.

POSITION OF CENTRE OF PRESSURE FOR PLANE AND CURVED SURFACES AT DIFFERENT ANGLES OF INCIDENCE

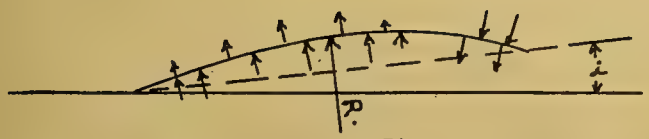

FIG. 2.

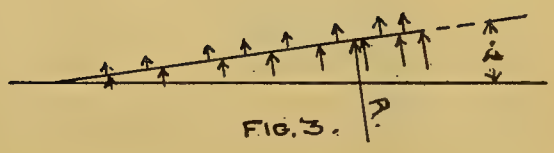

FIG. 3.

DIRECTION OF ACTION OF AIR PRESSURE ON MOVING CURVED AND PLANE SURFACES.

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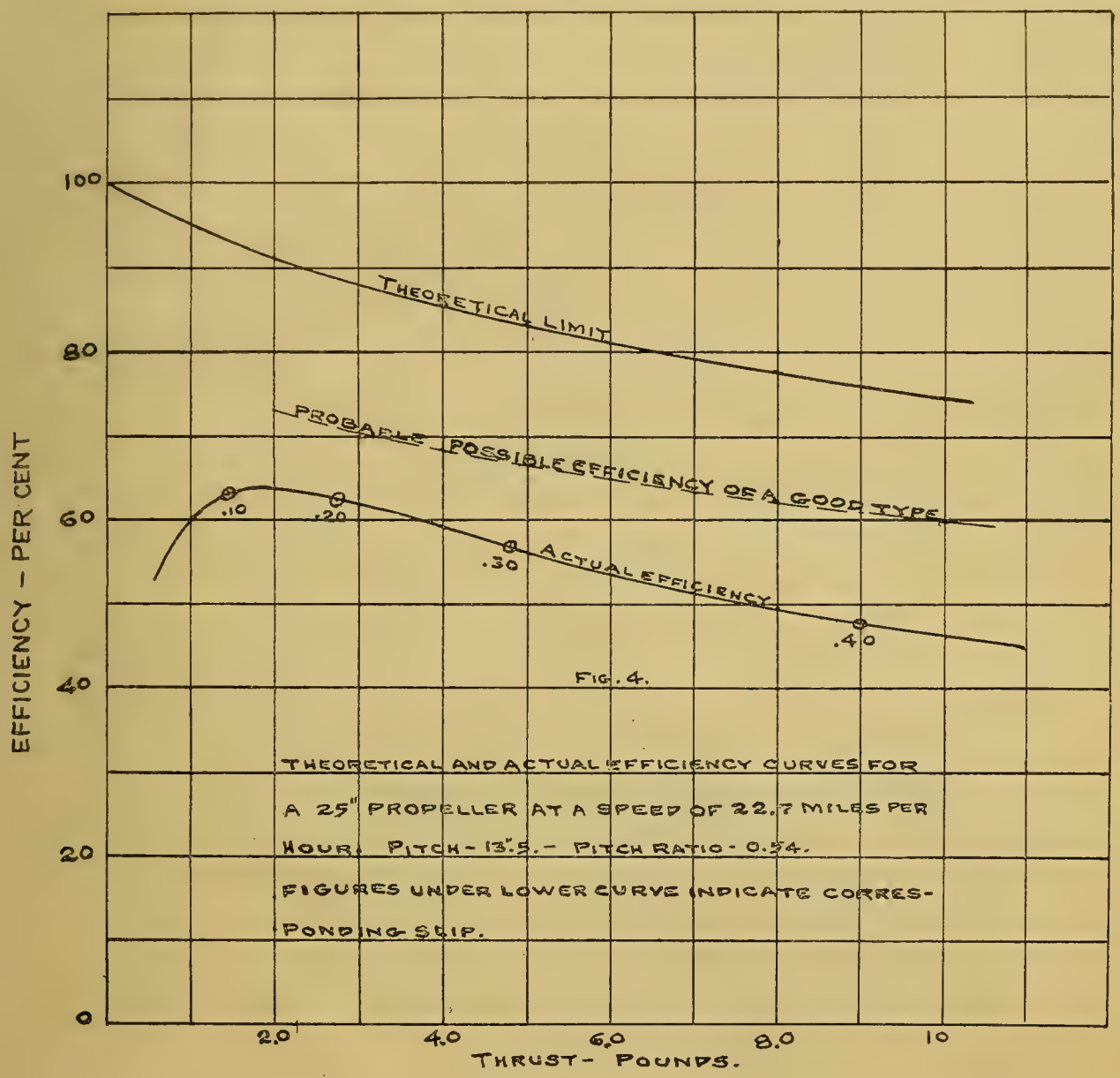

FIG. 4.

THEORETICAL AND ACTUAL EFFICIENCY CURVES FOR A 25" PROPELLER AT A SPEED OF 22.7 MILES PER HOUR. PITCH – 13".5. – PITCH RATIO – 0.54. FIGURES UNDER LOWER CURVE INDICATE CORRESPONDING SLIP.

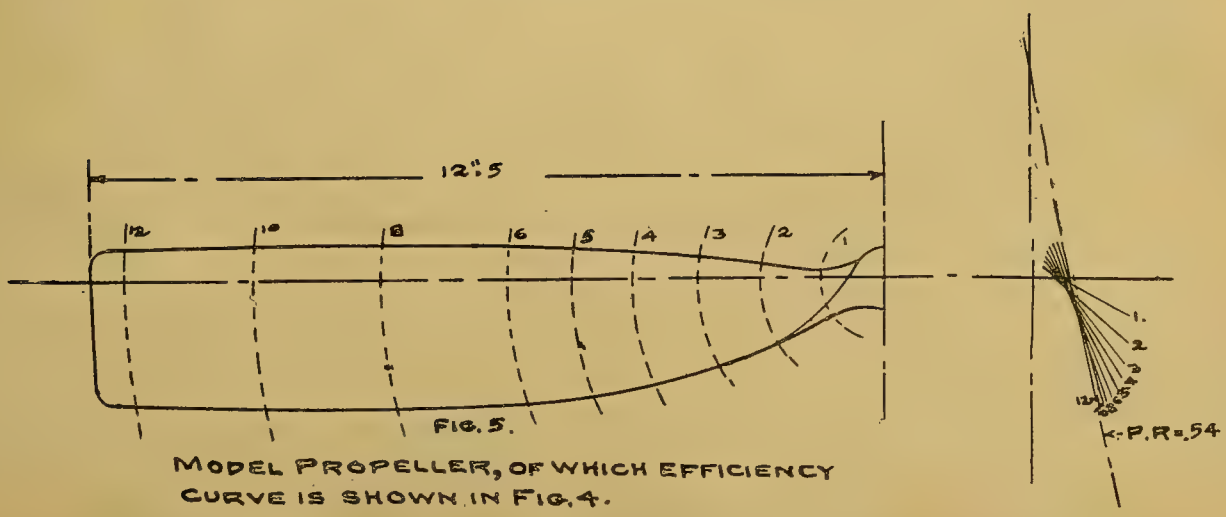

FIG. 5.

MODEL PROPELLER, OF WHICH EFFICIENCY CURVE IS SHOWN IN FIG. 4.

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